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(54) MAGNETIC RESISTANCE EFFECTIVE MEMORY, REPRODUCING METHOD FOR INFORMATION STORED IN THE MEMORY, AND ITS REPRODUCING DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a MRAM which can be reproduced without applying positive and negative current pulses and to provide a method for reproducing information of this MRAM and a reproducing device using only a positive pulse or a negative pulse.
SOLUTION: A magnetic resistance effective memory has a magnetic resistance film consisting of a first magnetic layer, a non-magnetic layer, and a second magnetic layer formed on a substrate, a conductor line for recoding information arranged near this magnetic resistance film or a conductor line for both recording and reproducing information, and a magnetization fixing layer near a magnetic resistance film. The

magnetization of a reproduction layer being one of magnetic layers of a magnetic resistance film is oriented in one direction by this magnetization fixing layer, the center of current magnetic field-MR ratio minor loop is shifted, and reproducing information can be performed by only a positive or negative current pulse.

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CLAIMS

[Claim(s)]
[Claim 1] Magneto-resistive effect memory characterized by having the magnetization fixed bed which makes an one direction carry out orientation of the magnetization direction of said playback layer to the magnetic-reluctance film which consists of the playback layer / a non-magnetic layer / a memory layer formed on a substrate according to magnetic bonding strength.
[Claim 2] Magneto-resistive effect memory according to claim 1 characterized by said magnetic bonding strength being switched connection force.
[Claim 3] Magneto-resistive effect memory according to claim 1

characterized by said magnetic bonding strength being magnetostatic bonding strength.
[Claim 4] said magnetic-reluctance film -- receiving -- said substrate and opposite side -- a conductor -- the magneto-resistive effect memory according to claim 1 characterized by arranging the line.
[Claim 5] Magneto-resistive effect memory according to claim 1 characterized by said non-magnetic layer consisting of a conductor.
[Claim 6] Magneto-resistive effect memory according to claim 1 characterized by said non-magnetic layer consisting of an insulator.
[Claim 7] Magneto-resistive effect memory given in any 1 term of claim 1-6 to which said magnetization fixed bed is characterized by having the same lamination as said magnetic-reluctance film.
[Claim 8] Magneto-resistive effect memory given in any 1 term of claim 1-6 to which said magnetization fixed bed is characterized by having different lamination from said magnetic-reluctance film.
[Claim 9] Magneto-resistive effect memory given in any 1 term of claim 1-8 to which the magnetization direction of said magnetic-reluctance film is characterized in general by being field inboard to a film surface.
[Claim 10] Magneto-resistive effect memory according to claim 7 to which easy-axis lay length L of said magnetic-reluctance film and die-length P of the magnetization fixed bed are characterized by being chosen as the range of $P/L>2.5$.
[Claim 11] claim 1- to which the magnetization direction of said magnetic-reluctance film is characterized in general by the perpendicular thing to a film surface -- magneto-resistive effect memory given in any 1 term of 6 or 8.
[Claim 12] Magneto-resistive effect memory according to claim 11 characterized by preparing the non-magnetic layer which has conductivity between said magnetic-reluctance film and said magnetization fixed beds.
[Claim 13] The playback approach characterized by detecting information recorded by impressing the current field of an one direction to said magnetic-reluctance film, and detecting magnetic-reluctance change in case the information recorded on magneto-resistive effect memory according to claim 1 is reproduced.
[Claim 14] In the magneto-resistive effect memory which has a line and the magnetization fixed bed to which an one direction is made to carry out orientation of the magnetization direction of one magnetic layer of said magnetic-reluctance film the conductor arranged near the magnetic-reluctance film which consists of a magnetic layer / a non-magnetic layer / a magnetic layer, and said magnetic-reluctance film -- In the

approach of reproducing information currently recorded on the line by the sink and said memory layer in the current as the memory layer which records a playback layer and information for two magnetic layers of said magnetic-reluctance film -- using -- said conductor -- A line is made to generate a magnetic field for the current of only the any 1 direction of positive/negative according to the current of said one direction to the field of a sink and said magnetic-reluctance film. said conductor -- The orientation of the magnetization of said playback layer is made to carry out in the direction of the magnetic field generated according to the current of said one direction. The playback approach characterized by detecting magnetic-reluctance change which is a difference with the resistance of said magnetic-reluctance film in the condition that the resistance and said magnetic field of said magnetic-reluctance film in the condition that said magnetic field was impressed are not impressed, and reproducing recorded information.

[Claim 15] The playback approach according to claim 14 characterized by carrying out orientation of the magnetization of said playback layer in the magnetization direction of said magnetization fixed bed established near said magnetic-reluctance film in the condition that said magnetic field is not impressed.

[Claim 16] The regenerative apparatus characterized by having a means to supply the current of the one direction used in order to reproduce information recorded on magneto-resistive effect memory according to the playback approach indicated to claims 13 or 14, and a means to detect magnetic-reluctance change.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the memory using a magneto-resistive effect. In more detail, the power consumption at the time of the playback is small, and a memory property improves, and it is related with magneto-resistive effect memory and its playback approach available as cheap memory for suitable computer peripheral, and a regenerative apparatus with improvement in the speed of a circumference circuit.

[0002]

[Description of the Prior Art] An intense ED competition is developed in the memory device used for a computer or electronic equipment. A technique progresses at an ever-advancing speed and various new memory devices are proposed. In recent years, giant magneto-resistance (Giant Magneto Registance) is discovered by the magnetic-reluctance film which put the non-magnetic layer between ferromagnetic layers, and the magnetic sensor and memory device using this phenomenon are attracting attention. The generic name of the memory device which used the magnetic-reluctance film for below is set to MRAM.
[0003] In MRAM, 3 layer structures of two ferromagnetic layers and the thin non-magnetic layer pinched between them serve as a basic structural unit which records information. the case where the magnetization direction has gathered between two ferromagnetic layers which inserted the non-magnetic layer -- anti- -- the condition of "0" and "1" is recorded by the case, ****, using the phenomenon in which resistance differs.
[0004] In case the information currently recorded is read, an alternating current magnetic field weaker than the time of writing is impressed, and only one ferromagnetic layer changes the sense of the magnetization direction, measures a change in resistance in that case, and reads the condition of "0" and "1." Since information is recorded magnetically, MRAM is excellent in radiation resistance and has the advantage which did not volatilize theoretically, writes in at high speed and does not have a limit of a count. Since high density record can be easily performed by diverting the existing semiconductor technology, replacement of DRAM is expected in the future. For example, the proposal about use is made by JP,06-243673,A as a memory device.
[0005] The principle of operation of MRAM is shown below. Drawing 5 (a) is drawing showing the configuration of MRAM. On the substrate, it has the configuration which carries out a laminating to the order of the 1st magnetic layer 11, a non-magnetic layer 12, the 2nd magnetic layer 13, an insulating layer 80, and the write-in line (word line) 51. Multilayer structure is sufficient as magnetic-reluctance **** which consists of combination of a ferromagnetic layer and a non-magnetic layer.
[0006] The 1st magnetic layer 11, the 2nd magnetic layer 12, and these two ferromagnetic layers consist of combination of soft magnetic materials and a hard magnetic material, turn into a playback layer from which soft magnetic materials read information, and turn into a memory layer in which a hard magnetic material accumulates information. In drawing 5 (a), the playback layer and the 2nd magnetic layer 13 for which the 1st magnetic layer 11 used soft magnetic materials are a

memory layer using a hard magnetic material. Buffer layers, such as SiN and Ta, may be prepared between a substrate and the 1st magnetic layer 11.
[0007] Record actuation of MRAM is performed by changing the direction of magnetization of the 2nd magnetic layer 13 which turns into a memory layer by the field generated by the write-in line.
[0008] Drawing 5 (b) shows the case where "0" is written in. If a record current is perpendicularly passed from a rear face toward a transverse plane to a write-in line in space, a field will occur in the direction of an arrow head. When recording, it is enlarging the field to generate, and not only the 1st magnetic layer 11 that is a playback layer but the magnetization direction of the 2nd magnetic layer 13 which is a memory layer is written in rightward on space. This condition is "0."
[0009] Drawing 5 (c) shows the case where "1" is written in. If a record current is perpendicularly passed from a transverse plane toward a rear face to a write-in line in space, a field will occur in the direction of an arrow head. When recording, it is enlarging the field to generate, and not only the 1st magnetic layer 11 that is a playback layer but the magnetization direction of the 2nd magnetic layer 13 which is a memory layer is written in leftward on space. This condition is "1."
[0010] On the other hand, at the time of playback, a write-in line is made to reverse magnetization of a playback layer by passing a regenerative-current pulse weaker than the time of record in order in both directions, and it realizes by reading the resistance change at that time.
[0011] Drawing 5 (d) - (g) is a series of drawings showing playback actuation. In the condition that "0" is recorded as shown in drawing 5 (b), change of the magnetization direction of the magnetic layer at the time of, next passing the current of the reverse sense is perpendicularly shown in space from the transverse plane in the regenerative current toward the rear face to the write-in line at drawing 5 (d) at a sink and drawing 5 (e), respectively at first.
[0012] As shown in drawing 5 (d), when the regenerative current is perpendicularly passed from a transverse plane toward a rear face at first to a write-in line in space, a small field occurs in the sense of an arrow head. Although magnetization reversed the 1st magnetic layer 11 which is a playback layer in this magnetic field strength, magnetization of the 2nd magnetic layer 13 which is a memory layer has maintained the direction of "0." When the regenerative current is perpendicularly passed from a rear face toward a transverse plane to a write-in line in space as shown in drawing 5 (e) next, a small field occurs in the sense

of an arrow head. Although magnetization re-reversed the 1st magnetic layer 11 which is a playback layer in this magnetic field strength, magnetization of the 1st magnetic layer 13 which is a memory layer has maintained the direction of "0."

[0013] When are observed in the magnetization direction of two magnetic layers and the regenerative current is perpendicularly passed toward a rear face from a transverse plane in the first space, the magnetization direction of the 1st magnetic layer 11 and the 2nd magnetic layer 13 is in an anti-parallel condition.

[0014] Next, when it writes in and the regenerative current is perpendicularly passed from a rear face toward a transverse plane to a line in space, the magnetization direction of the 1st magnetic layer 11 and the 2nd magnetic layer 13 is in an parallel condition. Therefore, it writes in, while passing a current pulse in the two directions, and resistance change of a line changes from high resistance of an anti-parallel condition to low resistance of an parallel condition. It can read that the condition that resistance changes from such high resistance to low resistance is "0."

[0015] Change of the magnetization direction of the ferromagnetism layer at the time of passing the current of the reverse sense for the regenerative current next to a sink and drawing 5 (g) to a write-in line at space toward [in the beginning] a transverse plane to a rear face in drawing 5 (f) in the condition that "1" is recorded as shown in drawing 5 (c) on the other hand, perpendicularly is shown, respectively.

[0016] As shown in drawing 5 (f), when the regenerative current is perpendicularly passed from a transverse plane toward a rear face at first to a write-in line in space, a small field occurs in the sense of an arrow head. In this field, as for the 1st magnetic layer 11 which is a playback layer, magnetization of the 2nd magnetic layer 13 the magnetization direction does not change and is [magnetic layer] a memory layer has also maintained the direction of "1." When the regenerative current is perpendicularly passed from a rear face toward a transverse plane to a write-in line in space as shown in drawing 5 (g) next, a small field occurs in the sense of an arrow head. This magnetic field strength of the 1st magnetic layer 11 which is a playback layer is insufficient for changing magnetization of the 2nd magnetic layer which is a memory layer, although magnetization is reversed, and the direction of "1" has been maintained.

[0017] When it observes in the magnetization direction of two magnetic layers, and the regenerative current is perpendicularly passed from a transverse plane toward a rear face to a write-in line in space at first,

the magnetization direction of the 1st magnetic layer 11 and the 2nd magnetic layer 13 is in an parallel condition. Next, when the regenerative current is perpendicularly passed toward a transverse plane from a rear face in space, the magnetization direction of the 1st magnetic layer 11 and the 2nd magnetic layer 13 is in an anti-parallel condition. Therefore, it writes in, while passing a current pulse in the two directions, and resistance change of a line changes from low resistance of an parallel condition to high resistance of an anti-parallel condition. It can read that the condition that resistance changes from such low resistance to high resistance is "1."

[0018] As stated above, the information currently recorded by reading the resistance change when writing in a weak current pulse and passing on a line can identify "0" and "1." This record playback approach can expect an ideal memory property from a high-speed drive being possible by un-volatilizing and un-destroying. It is divided into the absolute detection which will compare size with the resistance itself if it divides roughly, and the differential detection the resistance change at the time of shaking a current in the two directions judges the increment direction or the reduction direction to be although the various proposals of the approach of detecting electrically the magnetic-reluctance change at the time of said playback are made.

[0019] Although it wrote in and the above-mentioned explanation of operation explained the record / playback approach of the memory using a line, a write-in line is not indispensable as a component of MRAM. Other adjoining wiring can also be diverted to generating of the field which reverses magnetization of a ferromagnetic layer depending on structure.

[0020] When it classifies from a viewpoint of the mechanism of the ingredient using the configuration of MRAM, and magnetic reluctance, there are the spin dispersion mold which used the metal non-magnetic layer for the interlayer, a spin bulb mold which fixed the magnetization direction of one ferromagnetic layer in the antiferromagnetism layer, a spin tunnel mold using an insulator non-magnetic layer, other granular molds which distributed the particle of a magnetic material in the non-magnetic layer, a CMR (Colossal Magnetoresistance) mold using a perovskite oxide film, etc.

[0021] In a spin dispersion mold, GMR discovers a non-magnetic layer by spin dependence dispersion between two magnetic layers as metal layers, such as Cu. That is, although the electrons with the spin of magnetization and an opposite direction are scattered about when the sense of magnetization of a magnetic layer is parallel, the electrons with the spin of magnetization and the same direction are not scattered

about, but resistance becomes low as a whole. on the contrary, the sense of magnetization of a magnetic layer -- anti- -- case **** -- magnetization -- said -- since both an electron with direction spin and electrons with the spin of an opposite direction are scattered about, resistance becomes high as a whole. Although the MR ratio is larger than the anisotropy magneto-resistive effect which about 5 - 10% is obtained at a room temperature, and is decided in a current and the direction of magnetization, it is smaller than a spin tunnel mold.

[0022] It differs in that the spin bulb mold is carrying out pinning of the magnetization direction but theoretically by the same thing as spin dispersion for which an antiferromagnetism layer is combined with one ferromagnetic layer. The magnetization direction of another magnetic layer can be rotated freely. If a magnetization curve is taken, in order to become an unsymmetrical configuration according to the magnetization direction and to change from low resistance to high resistance near a zero field at linearity, it has structure suitable for the magnetic sensor which carries out sensing of the minute MAG. In current, it is put in practical use as a reading sensor of a hard disk.

[0023] With a spin tunnel mold, an electron carries out tunneling of the insulator by using a non-magnetic layer as an insulator, it moves between two magnetic layers, and a magneto-resistive effect is discovered in the form depending on the difference of the density of states of a spin electron. That is, when the sense of magnetization of a magnetic layer is parallel, since the electron which has down spin in the condition of rise spin that another ferromagnetic layer was vacant as for the electron with rise spin can be tunneled in the condition of the down spin as for which another ferromagnetic layer was vacant, the difference of the density of states of a spin electron becomes small, and resistance becomes low. on the contrary, the sense of magnetization of a magnetic layer -- anti- -- in ****, since neither an electron with rise spin nor an electron with down spin can be tunneled, the difference of the density of states of a spin electron becomes large, and resistance becomes high. 10% - about 30% is obtained at a room temperature, and the MR ratio is larger than a spin dispersion mold. However, the component resistance itself is stronger than a spin dispersion mold because of the structure which sandwiched the insulator. The research of the magnetic-reluctance film done the spin bulb mold using the antiferromagnetism film is briskly studied as an object for next-generation hard disk reading sensors, using this spin tunneling.

[0024] Two sorts, the spin dispersion type which used the metal as a non-magnetic layer, and the spin tunnel type using an insulator, exist

in a granular mold. In the spin dispersion mold which carried out point **, or a spin tunnel mold, the point which discovers GMR in the form for which it depends on the spin of each detailed magnetic particle distributed in the matrix in a granular mold to having clarified the role assignment for each class is a big difference. In the spin tunnel type of a Co/AlOx system, about 8% of MR ratio is obtained at the room temperature.

[0025] In a CMR mold, the type made into the tunnel junction which put Mn oxide of a perovskite structure with the higher perovskite Mn oxide of the rate of spin polarization, the type which uses the layer structure in perovskite as a tunnel junction exist. Since the rate of spin polarization of a CMR mold is very high, in very low temperature, no less than 400% of MR ratio is obtained.

[0026] It will be divided into a field inner magnet-ized membrane type with a magnetization component parallel to a film surface, and a perpendicular-magnetic-anisotropy-films mold with a magnetization component perpendicular to a film surface if the magnetic material used for MRAM is classified according to the magnetization direction. Although the magnetization direction is a field inner magnet-ized membrane type parallel to a film surface, since magnetic poles will approach and an anti-field will become large if detailed-ization of the magnetic substance progresses, ferromagnetics, such as NiFe and Co, have the problem that the curling phenomenon of magnetization occurs, by this field inner magnet-ized film. If curling occurs, it will become difficult to distinguish the direction of magnetization. Therefore, in MRAM using the field inner magnet-ized film, since shape anisotropy is given, it is necessary to consider as the configuration which looks at the ferromagnetic layer used as a memory cell superficially, and has a major axis (rectangle etc.). It is expected that the ratio of a rectangular major axis and a rectangular minor axis is required more than twice [at least]. Therefore, for curling phenomenon prevention, the size of a memory cell receives constraint and becomes the inhibition factor of the improvement in a degree of integration.

[0027] On the other hand, when using the ferrimagnetic substance which consists of rare earth-transition metals, such as TbFe, TbFeCo, and GdFe, as a ferromagnetic layer, since the perpendicular magnetic anisotropy of these magnetic substance is high, it becomes thickness and the perpendicular magnetic anisotropy films which have magnetization perpendicularly to a film surface depending on a presentation. In the case of perpendicular magnetic anisotropy films, the direction of magnetization has turned to the film surface perpendicular direction

where an anti-field is geometrical the largest, and when a perpendicular magnetic anisotropy is shown, the maximum demagnetization factor will already be overcome. That is, it is not necessary to make a memory cell into a rectangle like the field inner magnet-ized film, and the flat-surface configuration of a memory cell can be made into a square. Furthermore, if a component is made detailed, since a superficial area will become small compared with the direction of thickness which is an easy axis, in the viewpoint of shape anisotropy, the curling of magnetization becomes in the direction which cannot occur more easily. Therefore, the perpendicular-magnetic-anisotropy-films mold is advantageous compared with a field inner magnet-ized membrane type, when improving the degree of integration of the memory cell section.

[0028] The direction of a current is divided roughly into CPP (CurrentPerpendicular to the Plane) perpendicular to parallel CIP (Current In Plane) by how to pass the current over MRAM, or the method of arrangement of an electrode to a film surface. Each electrode structure is shown in drawing 6 .

[0029] As shown in drawing 6 (a), CIP is the structure which the sense layer attached to the both-sides side of the memory cell which consists of the 1st magnetic layer / a non-magnetic layer / the 2nd magnetic layer, and a sense current flows in parallel with a film surface. The dotted line is illustrating one side of a sense layer among drawing 6 (a). In CIP, the magnetic-reluctance film of a spin dispersion mold is used. In that case, the sheet resistance of about 10ohms and a sense line is set to 0.05 ohms by resistance of one cel by sheet resistance. Moreover, magnetic-reluctance rate of change is small as compared with about 5 - 10%, and a spin tunnel mold. When carrying out series connection of many cels to a sense line with CIP structure and carrying out signal detection at the both ends, in order to make resistance change for one cel into a signal to the combined resistance which added together the resistance of the connected a large number cel, it is not easy to attain high SN.

[0030] As shown in drawing 6 (b), CPP is the structure of the memory cell which consists of the 1st magnetic layer / a non-magnetic layer / the 2nd magnetic layer which the sense line attached up and down. A sense current flows between up-and-down sense lines perpendicularly to a film surface. The dotted line shows the up sense layer among drawing 6 (b). In CPP, it is good to use the magnetic-reluctance film of a spin tunnel mold, and resistance of one cel is the range about [several kohms to] several 10komega in that case, and resistance is large compared with a sense line. Moreover, magnetic-reluctance rate of change

also becomes about 10 - 30%, and is large as compared with a spin dispersion mold. That is, even if it connects the magnetic-reluctance film to a sense line, a sufficiently big resistance change is obtained, and therefore, high SN is obtained.

[0031] With this CPP structure, in order to arrange a cel at the crossing of a sense line, when arranging many cels, each cel is connected to juxtaposition. With this configuration, since it can detect without seldom being influenced of other cels by passing a current to the sense line which intersects that cel when detecting resistance of a specific cel, compared with CIP structure, SN becomes high. Therefore, compared with CIP structure, CPP structure can form easily a matrix with it. [there are many cels connectable with the sense line of one train, and large-scale] That is, when putting in order and driving many memory cells as a memory device is considered, the CPP structure is more advantageous than CIP structure.

[0032]

[Problem(s) to be Solved by the Invention] In case differential detection is used in MRAM, "0" and "1" are identified by carrying out differential detection of the resistance change when passing the current of positive/negative by turns. In order to generate the current of positive/negative, a bipolar power supply is needed. When realizing a high-speed bipolar function, in order to reverse the sense of a current, it is important to change some switches to a high speed to exact timing. If a gap arises to timing, a ringing and overshoot will occur in a current wave form. Since these cause malfunction, they must be controlled as much as possible. It becomes a problem, when the tooth space which optimization of the power circuit in consideration of the wiring capacity used as a delay element, load resistance, etc. is indispensable, and combines with transistor extension for switching function implementation, and a power circuit occupies increases and the degree of integration as memory is improved, in order to control a ringing and overshoot. Since it becomes the evil which raises a degree of integration, it also becomes the factor which makes a unit price high per bit of memory.

[0033] Recently, instead of the headphone stereo cassette tape recorder of the Walkman type which used the tape medium as a field of the invention of solid-state memory, the MP3 player attracts attention. If it applies to an MP3 player, the advantage of solid-state memory will be demonstrated by full in viewpoints, such as earthquake resistance, endurance, and a miniaturization. In addition, a mechanical drive part is not needed but the advantage of a low power can also be employed

efficiently. Moreover, it replaces with the source only for playbacks currently supplied by CD, MD, etc., and it is assumed that supply of the source only for playbacks using solid-state memory is made.
[0034] the case of MRAM where it uses for the needs only for such playbacks is considerable -- a number of -- ** -- although it thinks, in case the spread is aimed at, the tooth-space cost of the exclusive bipolar power supply used for playback which is mentioned above cannot be disregarded.
[0035] If signal regeneration of MRAM can be realized by passing the current pulse of one of positive/negative, the above-mentioned problem will be solved. the time of reproducing -- a conductor -- if a bipolar function becomes unnecessary in the power circuit added to a line, circuitry can be simplified and, in addition, a manufacturing cost will also fall. Moreover, constraint of the improvement in a degree of integration is lost, and it becomes possible to advance reduction of a unit price easily per bit. Signal regeneration using the current of one of the positive/negative of a certain thing in such a request was not realized.
[0036] This invention solves the aforementioned technical problem, and the purpose of this invention is to offer the approach of reproducing the information on this MRAM, and the regenerative apparatus used for it only using offer of refreshable MRAM, and a forward or negative current pulse, without impressing the current pulse of positive/negative. Thereby, a MRAM property is improved and it aims at realizing cheap memory for more suitable computer peripheral with improvement in the speed of a circumference circuit.
[0037]
[Means for Solving the Problem] As a result of inquiring wholeheartedly that it should solve in the above-mentioned technical problem, this invention persons produced refreshable MRAM, without impressing the current pulse of positive/negative, thereby, improved the MRAM property and made realizable cheap memory for more suitable computer peripheral with improvement in the speed of a circumference circuit. That is, this inventions are the magneto-resistive effect memory which has the configuration indicated in each item of (1) - (12) which carries out the following, and a regenerative apparatus shown in the playback approach of the information recorded on this magneto-resistive effect memory indicated in each term of - (15), and (13) (16) term.
[0038] (1) Magneto-resistive effect memory characterized by having the magnetic-reluctance film which consists of the 1st magnetic layer / a non-magnetic layer / the 2nd magnetic layer formed on a substrate, and

the magnetization fixed bed to which an one direction is made to carry out orientation of the magnetization direction of said 1st magnetic layer or the 2nd magnetic layer according to magnetic bonding strength.

[0039] (2) Magneto-resistive effect memory given in the term (1) characterized by said magnetic bonding strength being switched connection force.

[0040] (3) Magneto-resistive effect memory given in the term (1) characterized by said magnetic bonding strength being magnetostatic bonding strength.

[0041] (4) said magnetic-reluctance film -- receiving -- said substrate and opposite side -- a conductor -- magneto-resistive effect memory given in the term (1) characterized by arranging the line.

[0042] (5) Magneto-resistive effect memory given in the term (1) characterized by said non-magnetic layer consisting of a conductor.

[0043] (6) Magneto-resistive effect memory given in the term (1) characterized by said non-magnetic layer consisting of an insulator.

[0044] (7) Magneto-resistive effect memory given in any 1 term of term (1)-(6) to which said magnetization fixed bed is characterized by having the same lamination as said magnetic-reluctance film.

[0045] (8) Magneto-resistive effect memory given in any 1 term of term (1)-(6) to which said magnetization fixed bed is characterized by having different lamination from said magnetic-reluctance film.

[0046] (9) Magneto-resistive effect memory given in any 1 term of term (1)-(8) to which the magnetization direction of said magnetic-reluctance film is characterized in general by being field inboard to a film surface.

[0047] (10) Magneto-resistive effect memory given in the term (7) to which easy-axis lay length L of said magnetic-reluctance film and die-length P of the magnetization fixed bed are characterized by being chosen as the range of $P/L>2.5$.

[0048] (11) Term (1)-(6) to which the magnetization direction of said magnetic-reluctance film is characterized in general by the perpendicular thing to a film surface, or magneto-resistive effect memory given in any 1 term of (8).

[0049] (12) Magneto-resistive effect memory given in the term (11) characterized by preparing the non-magnetic layer which has conductivity between said magnetic-reluctance film and said magnetization fixed beds.

[0050] (13) The playback approach characterized by detecting information recorded by impressing the current field of an one direction to said magnetic-reluctance film, and detecting magnetic-reluctance change in case the information recorded on magneto-resistive effect memory given

in a term (1) is reproduced.
[0051] (14) the conductor arranged near the magnetic-reluctance film which consists of a magnetic layer / a non-magnetic layer / a magnetic layer, and said magnetic-reluctance film -- with a line In the magneto-resistive effect memory which has the magnetization fixed bed to which an one direction is made to carry out orientation of the magnetization direction of one magnetic layer of said magnetic-reluctance film In the approach of reproducing information currently recorded on the line by the sink and said memory layer in the current as the memory layer which records a playback layer and information for two magnetic layers of said magnetic-reluctance film -- using -- said conductor -- A line is made to generate the current magnetic field of the one direction according the current of only the any 1 direction of positive/negative to the current of said one direction to the field of a sink and said magnetic-reluctance film. said conductor -- The orientation of the magnetization of said playback layer is made to carry out in the direction of the magnetic field generated according to the current of said one direction. The playback approach characterized by detecting magnetic-reluctance change which is a difference with the resistance of said magnetic-reluctance film in the condition that the resistance and said magnetic field of said magnetic-reluctance film in the condition that said magnetic field was impressed are not impressed, and reproducing recorded information.
[0052] (15) The playback approach given in the term (12) characterized by carrying out orientation of the magnetization of said playback layer in the magnetization direction of said magnetization fixed bed established near said magnetic-reluctance film in the condition that said magnetic field is not impressed.
[0053] (16) The regenerative apparatus characterized by having a means to supply the current of the one direction used in order to reproduce information recorded on magneto-resistive effect memory according to the playback approach indicated in any 1 term of a term (13), (14), or (15), and a means to detect magnetic-reluctance change.
[0054]
[Embodiment of the Invention] the conductor which replaces with it and is arranged near the magnetization fixed bed and the magnetic-reluctance film in MRAM of this invention at the flux reversal of a playback layer although the means which changes the impression direction of a current for the current conventionally passed to a word line at the time of playback of recording information to positive/negative in pulse is used -- a means to impress only the pulse current by the side of plus or

minus to a line is combined.
[0055] MRAM of this this invention is explained in more detail about that configuration and the playback approach of recording information using a drawing below.
[0056] The magnetization fixed bed is a magnetic layer to which is arranged near the magnetic-reluctance film and applied the field beforehand and which the one direction was made to carry out orientation first. Even if the function of this magnetization fixed bed removes an external magnetic field, it is making the situation of having magnetization by desired coercive force. If the quality of the material and thickness of the magnetization fixed bed are suitably chosen by the property of the magnetic-reluctance film and achieve an above-mentioned function with it, they will not be restricted to the configuration of the following examples.
[0057] The magnetization fixed bed is arranged near spatial to 1 set of magnetic-reluctance film used as a memory cell. A function impresses a field in the direction of an easy axis of the magnetic film which constitutes the magnetic-reluctance film, the initialization field which applied to which and set up the field from the exterior beforehand is held, and the current generating magnetic field which reproduces a signal keeps constant the magnetization direction of the 1st magnetic layer used as a playback layer in approximation at the time of zero. For this reason, the relation of the magnetization direction of the 1st magnetic layer and the 2nd magnetic layer can identify parallel or anti-parallel in [a regenerative-current generating magnetic field] approximation at the time of zero. That is, a signal is detectable by impressing the current of one of positive/negative. one conductor -- it can be determined as arbitration which is made forward (plus) among the two directions of the current passed on a line or whether it considers as negative (minus).
[0058] There are various approaches in production of this magnetization fixed bed. In case a memory cell is produced, some magnetic-reluctance film which formed membranes can be diverted as the magnetization fixed bed. Moreover, a different magnetic material apart from the magnetic-reluctance film of a memory cell may be formed, and the magnetization fixed bed may be prepared in the location which adjoins a memory cell. The bias field impression means in the magnetic head for hard disk stores currently indicated, for example in JP,10-312514,A etc. as a means to have the function of this magnetization fixed bed may be used.
[0059] The case where the spin dispersion film of the field inner magnet-ized film is used for the magnetization fixed bed is taken for an

example, and an operation of this invention is explained. An example of the configuration of a memory cell is shown in drawing 1 . As for the 1st ferromagnetic layer, and 12, 22 and 32, for 1, a non-magnetic layer, and 13, 23 and 33 are [a substrate, and 11, 21 and 31] the 2nd ferromagnetic layer. 11, 12, and 13 are doubled, the magnetic-reluctance film 10 doubles 21, 22, and 23, the magnetization fixed bed 20 doubles 31, 32, and 33, and the magnetization fixed bed 30 is formed. 41 -- a buffer layer and 51 -- a conductor -- a line is shown. a conductor -- a line 51 exists in right above [of the magnetic-reluctance film 10] through an insulating layer (not shown), and by drawing 1, in order to make it legible, it is divided and displayed on 51a and 51b.
[0060] at the time of informational record and playback, a sense current passes in the direction of an arrow head 100 in order of the magnetization fixed bed 20, the magnetic-reluctance film 10, and the magnetization fixed bed 30 -- having -- a conductor -- a WORD current is passed by the line 51 in the direction of arrow heads 101a and 101b. Both the 1st ferromagnetic layer 21 of the magnetization fixed bed 20 and the 1st ferromagnetic layer 31 of the magnetization fixed bed 30 are magnetized in the fixed direction within a field, and the magnetization carries out orientation of the 1st ferromagnetic layer 11 of the magnetic-reluctance film 10 according to the sense of the magnetization. Informational record and playback are performed by the synthetic field which a sense current and a WORD current generate by changing the magnetization direction of the 1st a little more than magnetic layer 11 of the magnetic-reluctance film 10.
[0061] Sense line lay length used as the memory cell of the magnetic-reluctance film 10 using the field inner magnet-ized film shown in drawing 1 is set to L, and the die length of W and the magnetization fixed bed is set to P for width of face. P is equivalent to spacing with the following memory cell, when many memory cells are located in a line.
[0062] Here, if it is chosen as the range of P/L>2.5, even if it will not shake a WORD current at both directions of positive/negative, playback of a signal can be performed only in forward or the negative current pulse which generates a field opposite to the initialization magnetization direction which impressed and set up the external magnetic field beforehand. That is, since the 1st magnetic layer 11 of the magnetic-reluctance film 10 is enclosed by the magnetization fixed beds 20 and 30 which turned to the initialization magnetization direction, its inclination to follow in the same direction as these both magnetization direction is strong. for example, -- if a WORD current serves as zero and the current magnetic field impressed to the 1st

magnetic layer 11 (playback layer) of the magnetic-reluctance film 10 becomes zero mostly, when it is anti-parallel to the 2nd ferromagnetic layer (memory layer) in which the aforementioned initialization magnetization direction wrote the signal of "1" -- anti- -- it will be stabilized in the condition [****].
[0063] Therefore, by the existence of the current pulse which generates a field opposite to the initialization magnetization direction, in the case of "0", it changes from high resistance to low resistance, and, in the case of "1", changes from low resistance to high resistance. If differential detection of this change is carried out, discernment of "0" and "1" is possible at a high speed.
[0064] The problem that a current big in case that P/L is larger than 2.5 records a signal as becoming but excessive required is needed like drawing 1 when using the spin dispersion film of a field inner magnetized membrane type as the magnetization fixed bed, or a signal regeneration margin becomes small occurs. Moreover, the smaller one is desirable also from a viewpoint of a degree of integration. Therefore, P/L is made or less into 50 and is good more desirably to choose it as the range of 2.5-10.
[0065] Although L and P are closely related to the amount of currents which the playback takes in the playback approach of using only the pulse current of one of the positive/negative of this invention, W is not concerned greatly. However, when W becomes small, the magnetization direction is in the inclination whose WORD current required for signal regeneration whose energy of the flux reversal at the time of playback increases, and increases, in order to be limited to a component parallel to L.
[0066] This phenomenon is further explained in full detail using drawing 1. The initialization magnetization direction which impressed and set up the external magnetic field beforehand to the whole memory array is made into the direction of -X. Therefore, the magnetic-reluctance film 10 in the case of passing no currents and the magnetization direction of the magnetization fixed beds 20 and 30 are the directions of -X. if the effect of the field which a sense current generates will not be considered in order to simplify explanation although the magnetization direction is decided by the synthetic field by the sense current and the WORD current on XY flat surface in fact -- the magnetization direction of a memory cell -- a conductor -- it is decided in the **X direction with the directions 102a and 102b of a generating field of a WORD current and the magnitude of a field which flow a line 51.
[0067] First, the case where the current of the positive/negative which

is the conventional playback approach is passed first is considered. The field which will be generated if a WORD current is passed in the direction of arrow-head 101a becomes in the direction of arrow-head 102a. If a field stronger than the coercive force of the 1st magnetic layer 11 is generated, magnetization of the 1st magnetic layer 11 will turn to the direction of arrow-head 102a. the 1st magnetic layer 11 -- a conductor -- since it is located under a line 51, the magnetization direction is the direction of +X. Next, if a WORD current is passed in the direction of arrow-head 101b, a field will be reversed in the direction of arrow-head 102b, and the magnetization direction of the 1st magnetic layer 11 will become in the direction of -X. Since the magnetization direction of the 2nd magnetic layer 13 is still the direction of -X made into the initialization magnetization direction, according to change of a WORD current, the relation of the magnetization direction of the 1st magnetic layer and the 2nd magnetic layer changes from anti-parallel to parallel. Therefore, resistance change observed by the direction of +X and the degree according to the WORD current which generates the field of the direction of -X turns into change to the low resistance from high resistance. This is in the condition of "0."

[0068] If a WORD current is passed in order of arrow heads 101a and 101b like "0" in the case of "1", the field to generate will change in order of arrow heads 102a and 102b, and the magnetization direction of the 1st magnetic layer 11 will change in the direction of -X from +X. Since the magnetization direction of the 2nd magnetic layer 13 is the direction of +X in "1", according to change of a WORD current, the relation of the magnetization direction of a magnetic layer and the 2nd magnetic layer changes from parallel to anti-parallel. Therefore, resistance change observed is doubled with the direction of +X, and the current which generates the field of the direction of -X next, and turns into change to the high resistance from low resistance. This is in the condition of "1."

[0069] Next, playback by the playback approach of this invention, i.e., the pulse current of one of positive/negative, is explained. What is necessary is just to pass the WORD current which generates the field of the direction of +X, since a signal is detectable by the current pulse which generates a field opposite to the initialization magnetization direction even if it does not shake a WORD current at positive/negative. If it says with the sense of a field in drawing 1, it will be arrow-head 102a and will be the direction of arrow-head 101a with a WORD current.

[0070] In the case of "0", the magnetization direction of the 2nd magnetic layer 13 is the direction of -X. If a WORD current is passed in

the direction of arrow-head 101a, magnetization of the 1st magnetic layer 11 will be suitable in the direction of +X. On the other hand, when not passing WORD current 101a, since the magnetization direction of the magnetization fixed beds 20 and 30 which enclose a perimeter is the direction of -X, the magnetization direction of the 1st magnetic layer 11 is the same direction of -X as the neighboring magnetization fixed beds 21 and 31. Therefore, it becomes low resistance from high resistance by the existence of a WORD current at the time of "0." This expresses "0."

[0071] In the case of "1", the magnetization direction of the 2nd magnetic layer 13 is the direction of +X. If a WORD current is passed in the direction of arrow-head 101a, magnetization of the 1st magnetic layer 11 will be suitable in the direction of +X. On the other hand, when not passing WORD current 101a, the magnetization direction of the 1st magnetic layer 11 is the same direction of -X as the neighboring magnetization fixed beds 21 and 31. This is because magnetic association of the magnetization fixed beds 20 and 30 which enclose a perimeter is stronger than the 2nd magnetic layer 13 which turned to the direction of +X. Therefore, it becomes high resistance from low resistance by the existence of a WORD current at the time of "1." This expresses "1."

[0072] That is, although two current pulses of positive/negative are impressed and the magnetization direction of the 1st magnetic layer 11 is reversed by the usual playback approach, the signal of "0" and "1" can be read by the playback approach of this invention by restoring the magnetization direction of the 1st magnetic layer 11 temporarily reversed by the forward or negative current pulse to origin in an operation of the above-mentioned magnetization fixed bed.

[0073] The difference between the playback approach in MRAM of this invention and the playback approach in the conventional MRAM which does not prepare the magnetization fixed bed is further explained to a detail using the minor loop Fig. of a field-MR ratio. Drawing 11 is a minor loop when not preparing the magnetization fixed bed, and is equivalent to the conventional playback approach. It is equivalent to the condition that drawing 11 (a) recorded "1" on "0", and drawing 11 (b) recorded it on the 2nd magnetic layer 13. Although the magnetic-field-strength width of face**H added at the time of playback is larger than the coercive force of the 1st magnetic layer 11 here, it is level smaller than the coercive force of the 2nd magnetic layer 13. In addition, drawing showing typically the magnetization condition of each magnetic layer in the magnetic-field-strength **H aforementioned maximum by the arrow head is appended to the both ends in drawing. Moreover, the notation has

shown each class of memory. As well as the minor loop, the direction of a course of a hysteresis was written by the arrow head. To "0" of drawing 11 (a), if +H field is impressed, magnetization of the 1st magnetic layer 11 was reversed, and will be high resistance become anti-parallel by the magnetization direction of both magnetic layers (MR size). even if it returns to a zero field from here, in order that residual magnetization may remain -- anti- -- a condition [****] is maintained. In order to return to an parallel low resistance condition (MR smallness), it is necessary to generate a field in the direction of -H. If -H field is impressed, magnetization of the 1st magnetic layer 11 will be reversed, and the magnetization direction of both magnetic layers will serve as anti-parallel, as considering the condition that "1" was recorded on the 2nd magnetic layer 13 shown in drawing 11 (b) on the other hand, but in order to return to an parallel condition after that, it is necessary to impress the field of the direction of +H. That is, when the current pulse of both positive/negative is used for the conventional MRAM in the case of playback and it did not generate the field of **H both directions, it was what cannot check the phenomenon which standup change of a magnetic-reluctance signal has reversed by "0" and "1."
[0074] The minor loop of the field-MR ratio at the time of the playback in MRAM of this invention which prepares the magnetization fixed bed in drawing 12 is shown. + MRAM shown in drawing 1 in case the field of the direction of H is generated -- a conductor -- pass the current of the direction of arrow-head 101a on a line. It is equivalent to the condition that drawing 12 (a) recorded "1" on "0", and drawing 12 (b) recorded it on the 2nd magnetic layer 13. Moreover, drawing showing typically the magnetization condition of each magnetic layer in the magnetic-field-strength **H aforementioned maximum by the arrow head is appended to the both ends in drawing. Moreover, the notation has shown each class of memory. As well as the minor loop, the direction of a course of a hysteresis was written by the arrow head. In the minor loop of MRAM of this invention, it shifts in the direction of +H compared with drawing 11 according to the effectiveness of the magnetization fixed beds 20 (21, 22, 23) and 30 (31, 32, 33). Specifically, the core (a dotted line shows among drawing) of a hysteresis has deviated in the direction of shift-amount +H shown by the arrow head. If it returns to a zero field once the direction of +H carries out field impression in connection with it, magnetization of the 1st magnetic layer 11 will return to the original condition according to an operation of magnetization of the magnetization fixed bed. namely, the condition that

"0" was recorded on the 2nd magnetic layer 13 -- (-- if it returns to a zero field after impressing drawing 12 (a)) and +H field, it will change from high resistance to low resistance (MR size -> smallness). It is "1" to the 2nd magnetic layer 13. In the condition of having been recorded, if it returns to a zero field after impressing (drawing 12 (b)) and +H field, it will change from low resistance to high resistance (MR smallness -> size). Therefore, the check of the phenomenon which how [that "0" starts only by the current pulse which generates the field of the direction of +H] depending on which a signal starts by "1" reverses, i.e., playback of a record signal, is attained.

[0075] Drawing 9 is the sectional view showing typically the magnetization condition of the 1st magnetic layer when making the current generating magnetic field by the WORD current into zero in approximation, and the 2nd magnetic layer in MRAM of this invention of a configuration of being shown in drawing 1 . Drawing 9 (a) shows the condition that drawing 9 (b) recorded "1" for the condition of having recorded "0" on the 2nd magnetic layer 13, respectively. Each magnetization direction of the 1st magnetic layer 11 has turned to the same initialization magnetization direction as the magnetization fixed beds 20 and 30 pinched from right and left. If the WORD current of the shape of a pulse which goes to a front face from a rear face to space is impressed from this condition, since the magnetization direction of the 1st magnetic layer 11 will be reversed only in the meantime, signal regeneration becomes possible.

[0076] It is also possible to use the magnetization fixed beds 62 and 63 by magnetic material which this magnetization fixed bed is not restricted to the spin dispersion film shown in drawing 1 , and is different from the magnetic-reluctance film like drawing 2 . When using the magnetization fixed bed of different lamination from such magnetic-reluctance film, spacing of P can be packed compared with the case where the spin dispersion film is used. In this case, P can be shortened by transposing the same magnetization as the magnetization fixed beds 20 and 30 by the spin dispersion film of the die length of P to the magnetic material which it has by the fewer volume, and it is possible to improve a degree of integration. What is necessary is for the magnetic material to be used, lamination, etc. just to adjust suitably the relation between die-length P of the magnetization fixed bed, and die-length L of the magnetic-reluctance film according to the pulse-like current value of one of the positive/negative used in the case of playback.

[0077] In the above-mentioned operation gestalt, the magnetic-reluctance

film and the magnetization fixed bed are prepared [near the pole], and, as for the magnetic bonding strength in that case, the switched connection force is dominant.
[0078] Also when an operation and function of the magnetization fixed bed explained above are not limited to the spin dispersion film and applied to MRAM of other classes, the same operation is acquired theoretically. For example, when the spin tunnel film of the field inner magnet-ized film is used for memory cell structure, it can use in the direction of an easy axis of a sense line as the magnetization fixed beds 20 and 30 by leaving the spin tunnel film continuously like drawing 3 like the case of the spin dispersion film shown in drawing 1 . In this case, in order to prevent a current flowing into a contiguity memory cell, it is required to open a tooth space P1 and to prepare the magnetization fixed bed. Moreover, even if the magnetization fixed bed does not use the spin tunnel film, it may form the magnetization fixed beds 62 and 63 by different magnetic material from the magnetic-reluctance film like drawing 4 . In that case, die length P2 can be shortened by transposing the same operation as the magnetization fixed beds 20 and 30 using the spin tunnel film of the die length P2 shown in drawing 3 to the magnetic material attained by the fewer volume. Spacing (P1+P2+P1) with the adjoining memory cell can be narrowed by that cause, and it becomes possible to raise a degree of integration further. What is necessary is for the magnetic material to be used, lamination, etc. just to adjust suitably spacing P1, the die length P2 of the magnetization fixed bed, and the relation of die-length L of the magnetic-reluctance film also in the configuration which uses the spin tunnel film for the magnetic-reluctance film according to the pulse-like current value of one of the positive/negative used in the case of playback. In addition, since the effectiveness of the magnetization fixed bed will not be attained if spacing P1 is enlarged, it is usually P2>>P1. Therefore, the die length P2 of the magnetization fixed bed is equivalent to spacing with the memory cell which adjoins substantially with a spin tunnel mold as well as die-length P of the magnetization fixed bed in a spin dispersion mold.
[0079] In the aforementioned operation gestalt, magnetostatic bonding strength is committing magnetic bonding strength dominantly from the physical relationship of the magnetic-reluctance film and the magnetization fixed bed.
[0080] In case a memory cell is arranged in the shape of a matrix, the magnetization fixed bed does not work only to one memory cell, and the same effectiveness is brought about also to the adjoining memory cell.

Drawing 10 is other examples which prepared the magnetization fixed bed by another magnetic material on the spin tunnel film, and expresses the example of a configuration which memory-array-ized the magnetic-reluctance film to 3x3. The display of the sign about the component part which is not used for explanation and a name is omitted on a drawing. moreover, the conductor located on the magnetic-reluctance film 103 and 203 and 303 since it is necessary to attain visualization on account of explanation -- the line is omitted. original -- magnetic-reluctance film 103 and 203 and 303 top -- a conductor -- a line -- a conductor -- it is arranged in parallel with lines 701 and 702. For example, the magnetization direction is mainly fixed to the both sides of the magnetic-reluctance film 203 and 202 by the magnetization fixed bed 623. Furthermore, though it is weak, it has the operation which fixes the magnetization direction also to the magnetic-reluctance film 102, 103, 302, and 303 in the perimeter.
[0081] In MRAM of this invention, the high non-magnetic material substrate of surface smoothness, such as Si wafer, a quartz, and SOI, is used for a substrate. the production approach of a SOI substrate -- ELTRAN -- law and SIMOX -- various methods, such as law, are applicable. As for the crystal orientation of Si on the front face of a substrate, (100) is desirable in that case.
[0082] In case the magnetic-reluctance film is formed on said substrate, a buffer layer adjusts surface free energy at the bottom from the 1st magnetic film, and it is inserted in order to realize interface structure where surface smoothness is more high. Although the insulator of various metals, such as Ta, Cu, and Cr, SiN, SiO2, and aluminum203 grade is used, it is not necessary to insert depending on how to choose a substrate ingredient and the ingredient of the magnetic-reluctance film. The range of 2-10nm is suitable for the thickness of a buffer layer. This is because there is a problem of the membraneous ununiformity by island-shape growth depending on the membrane formation approach when thinner than 2nm, and there is a problem of a productivity slowdown on the other hand when thicker than 10nm.
[0083] In the case of the spin dispersion film, a conductor is used as a non-magnetic layer. Although Cu, Ag, Au, aluminum, Mg, etc. are used, Cu is used more suitably. The range of 1-10nm is suitable for the thickness of a non-magnetic layer. When there is fear of pinhole generating by island-shape growth, magnetic reluctance may not be discovered in less than 1nm with the interaction of both magnetic layers and it exceeds 10nm on the other hand by the membrane formation approach, since spacing between both magnetic layers is too large to an electronic mean free

path and spin dependency dispersion decreases, this is because magnetic reluctance becomes small.

[0084] In the case of the spin tunnel film, an insulator is used as a non-magnetic layer. As an insulator, although oxides and nitrides, such as aluminum, Si, Cu, and Mg, are used, aluminum oxide with the Fermi level near other magnetic layers is used more suitably. The range of 0.5-5nm is suitable for the thickness of a non-magnetic layer. When there is fear of pinhole generating by island-shape growth, magnetic reluctance may not be discovered in less than 0.5nm with the interaction of both magnetic layers and it exceeds 5nm on the other hand by the membrane formation approach, since spacing between both magnetic layers is too large to an electronic mean free path and a tunneling probability decreases, this is because magnetic reluctance becomes small.

[0085] The combination of the 1st magnetic layer which is the component of the magnetic-reluctance film, and the 2nd magnetic layer may consist of soft magnetic materials and a hard magnetic material, and the combination which not only the combination that the 1st magnetic layer uses as a soft magnetism layer, and the 2nd magnetic layer uses as a hard magnetism layer but the 1st magnetic layer uses as a hard magnetism layer, and the 2nd magnetic layer uses as a soft magnetism layer may be used. Soft magnetic materials function as a playback layer, in order that magnetization may be easily reversed. Compared with soft magnetic materials, since it is hard to reverse magnetization, a hard magnetic material functions as a memory layer. In addition, it sets to this invention, and distinction of soft magnetic materials and a hard magnetic material is defined by the size relation of the coercive force between two ferromagnetic layers, and makes relatively what has large coercive force a hard magnetic material.

[0086] Moreover, functions may be indicated to be the 1st magnetic layer and the 2nd magnetic layer, and although there is also a case of the monolayer which consists of a single element, the multilayer structure of various alloys is sufficient as each magnetic layer itself. For example, in order to make it function as a hard magnetic material, what carried out pinning as the two-layer structure of Co with a thickness of 5nm and FeMn with a thickness of 30nm can be used as the 1st (or the 2nd) magnetic layer. As the 1st magnetic layer and the 2nd magnetic layer, the ferrimagnetic substance, such as ferromagnetic ingredients, such as nickel, Fe, Co, NiFe, NiFeCo, FeCo, and CoFeB, and TbFe, TbFeCo, GdFe, is used. The presentation of these 2 magnetic layer is suitably adjusted so that the coercive force may differ. It is suitable for the thickness of the 1st magnetic layer and the 2nd magnetic layer to choose

it as the range of 2-100nm.
[0087] When the direction of magnetization has turned to the film surface perpendicular direction where an anti-field is geometrical the largest in the case of perpendicular magnetic anisotropy films and a perpendicular magnetic anisotropy is shown, the maximum demagnetization factor is already overcome. Therefore, even when a component is made detailed, it is hard to generate curling. Moreover, since it is not necessary like the field inner magnet-ized film to make a superficial configuration into a rectangle in order to prevent curling, when improving the degree of integration of the memory cell section, perpendicular magnetic anisotropy films are advantageous compared with the field inner magnet-ized film.
[0088] Drawing 13 is drawing showing the example of a configuration of the spin tunnel structure where perpendicular magnetic anisotropy films were used as a ferromagnetic layer. In drawing 13 , it superimposes on the magnetic-reluctance film 10 which consists of the 1st magnetic layer 11, a non-magnetic layer 12, and the 2nd magnetic layer 13, and there are a non-magnetic layer 64 and the magnetization fixed bed 62. between a substrate 1 and the magnetic-reluctance film 10 -- a conductor -- a line 71 -- the magnetization fixed-bed 62 top -- a conductor -- there is a line 72 and it functions as a lower sense line and an up sense line, respectively. the sense current which carries out signal regeneration -- a conductor -- a line 71, the magnetic-reluctance film 10, a non-magnetic layer 64, the magnetization fixed bed 62, and a conductor -- between lines 72 is flowed. an insulator layer -- minding -- a conductor -- there is a line 51 and it functions as a word line which generates a current field near the magnetic-reluctance film. As long as the 1st magnetic layer 11 and the magnetization fixed bed 62 are in near in location, the order of a laminating of the magnetic-reluctance film and the magnetization fixed bed may be reverse.
[0089] In the zero state, signs that the magnetization direction of the 1st magnetic layer 11 is being fixed to the same direction are typically expressed with work of the magnetization fixed bed 62 to drawing 13 using the arrow head in [a current field] approximation. The arrow head in the magnetization fixed bed 62, the 1st magnetic layer 11, and the 2nd magnetic layer 13 shows each magnetization direction. the case of signal regeneration -- a conductor -- the sense of the 1st magnetic layer 11 is reversed with the synthetic field of the field by the WORD current passed on a line 51, and the field by the sense current, and the condition of "0" and "1" can be judged with combination with the magnetization direction of the 2nd magnetic layer. In this case, the

magnitude of the magnetic bonding strength committed between the magnetization fixed bed 62 and the 1st magnetic layer 11 is adjusted by changing the thickness of a non-magnetic layer 64. It is suitable for the thickness of a non-magnetic layer 64 to choose it as the range of 2nm - 20nm. Although this is based also on the ingredient and thickness of the magnetization fixed bed 62, the magnetic bonding strength of the magnetization fixed bed 62 and the 1st magnetic layer 11 will become it large that it is less than 2nm too much, it will carry out, the effect of the magnetization fixed bed 62 concerning the 1st magnetic layer 11 will become large too much, and its WORD current required for playback will increase. On the other hand, if it exceeds 20nm, since the effectiveness of the magnetization fixed bed 62 will be hard to be acquired, it is because it is necessary to increase the volume of the magnetization fixed bed 62 and to change into the magnetic material with the large magnetization per unit volume in enlarging magnetization.
[0090] Also when perpendicular magnetic anisotropy films are used, even if it does not shake a WORD current at both directions of positive/negative by [, such as thickness and an ingredient] choosing conditions suitably, playback of a signal can be performed only in forward or the negative current pulse which generates a field opposite to the initialization magnetization direction which impressed and set up the external magnetic field beforehand.
[0091] Although the magnetic-reluctance film which consists of the 1st magnetic layer / a non-magnetic layer / the 2nd magnetic layer functions as a memory cell, the magnitude of the plane-of-composition product is suitably determined according to the process and use application to be used. Since the resistivity standardized in the area of the magnetic-reluctance film is about two 10-5ohmcm, two or less [which suits to the value (several kohms) of the on resistance of a transistor which drives a memory cell / 1-micrometer] are suitable for it.
[0092] the conductor on the magnetic-reluctance film -- organic materials, such as inorganic materials, such as SiO2, and SiN, aluminum 2O3, and novolak resin, are used for the insulating layer prepared between lines. If the thickness of an insulating layer is decided by required withstand voltage to the power impressed to a sense line or a word line and is chosen as the range of 5-1000nm, it is suitable.
[0093] In the case of the spin dispersion film, the synthetic field which a sense current and a WORD current generate performs informational writing. In the case of the spin tunnel film, it realizes by generating a field using the sense current passed to either of the vertical sense lines, or both, and determining the magnetization direction of a memory

layer. Or the field by the WORD current established through the insulating layer may be used. Record can be ensured when using a word line.
[0094] a conductor -- conductive high ingredients, such as aluminum, and Cu, Au, are used for a line. a conductor -- the thickness of a line is a rule thing in the current and line breadth to impress, and is chosen as the range of 100-1000nm -- having -- a conductor -- a line is used for informational record and playback.
[0095] The micro-processing patterning technique represented by photolithography can perform easily processing to each the above-mentioned ingredient and layer. A membrane formation process can apply various well-known approaches, such as vacuum evaporationo, sputtering, and MBE.
[0096]
[Example] An example is given to below and this invention is explained more concretely. In addition, although the following examples are examples of the gestalt of the best operation of this invention, this invention does not receive limitation according to these examples.
[0097] (Example 1) An example of the structure of MRAM of this invention used for drawing 1 by this example is shown. Drawing 1 shows the configuration which prepared the magnetization fixed bed of the same lamination as this magnetic-reluctance film to the spin dependence dispersion mold magnetic-reluctance film of the field inner magnet-ized film. Co is used as Cu and 2nd ferromagnetic layer of 13, 23, and 33 as a non-magnetic layer of nickel80Fe 20, 12, 22, and 32 as Si wafer and 1st ferromagnetic layer of 11, 21, and 31 as a substrate of 1. 11, 12, and 13 are doubled, the magnetic-reluctance film 10 doubles 21, 22, and 23, the magnetic fixed bed 20 doubles 31, 32, and 33, and the magnetic fixed bed 30 is formed. as the buffer layer of 41 -- SiN and the conductor of 51 -- aluminum is used as a line. a conductor -- the line 51 exists through the insulating layer SiN which is not illustrated right above [of the magnetic-reluctance film 10], and by drawing 1, in order to make it legible, it is divided and displayed on 51a and 51b.
[0098] A photolithography and lift off were used together in processing of a component, and the component pattern was formed in it. Drawing 7 (a) - (f) is drawing showing the processing procedure. As for (b), drawing 7 (c), (d) and drawing 7 (e), and (f), the top view, drawing 7 (b), (d), and (f) have shown the sectional view in the X-X' line in said top view to drawing 7 (a), (c), and (e) for the pair for each [nothing and] process of every, respectively. [drawing 7 (a),]
[0099] First, in order to form membranes to die-length L+2P and the

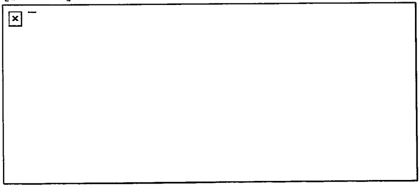
component pattern of width of face W which are shown in drawing 7 (a), an isomorphism-like resist mask is produced by the photolithography. The substrate which prepared the membrane formation mask is put into a sputtering system, and membranes are formed. On the conditions of 5x10 -5 or less Pa of ultimate-pressure force, sequential membrane formation of the Co which are Cu and the 2nd magnetic layer 13, 23, and 33 which are nickel80Fe20 and the non-magnetic layers 12, 22, and 32 which are SiN and the 1st magnetic layer 11, 21, and 31 which are buffer layers 41 is carried out. For SiN, 10nm and nickel80Fe20 are [the thickness / 5nm and Co of 10nm and Cu] 10nm. Here, nickel80Fe20 of the 1st magnetic layer is soft magnetic materials, and as a playback layer, Co of the 2nd magnetic layer is a hard magnetic material, and it functions as a memory layer. At the time of membrane formation, the permanent magnet is arranged so that it may have the same magnetic anisotropy as the direction of a substrate front face. Magnetic field strength which a permanent magnet generates was set to 20Oe(s) focusing on measurement. The laminated structure which shows a cross-section configuration to drawing 7 (b) is obtained by an acetone's performing ultrasonic cleaning after membrane formation, and removing and carrying out lift off of the excessive film deposited on a resist to a resist and coincidence.

[0100] Next, a resist mask is produced by the photolithography so that it may become the insulator layer of the flat-surface configuration shown in drawing 7 (c). The substrate which prepared the mask is put into a sputtering system, and SiN is formed 350nm in thickness. The insulator layer SiN which shows a cross-section configuration to drawing 7 (d) is obtained by an acetone's performing ultrasonic cleaning after membrane formation, and removing and carrying out lift off of the excessive SiN film deposited on a resist to a resist and coincidence.

[0101] next, the conductor of the flat-surface configuration shown in drawing 7 (e) -- a resist mask is produced by the photolithography so that it may become a line 51 and probe putt. The substrate which prepared the mask is put into a sputtering system, and aluminum is formed 400nm in thickness. the conductor which shows a cross-section configuration to drawing 7 (f) a resist, simultaneously by removing and carrying out lift off for excessive aluminum film which performed ultrasonic cleaning with the acetone after membrane formation, and has been deposited on a resist -- a line 51 and probe putt are obtained and a desired component is completed. aluminum film of 100-micrometer angle which formed membranes so that the both ends of the magnetic-reluctance film might be contacted functions as a pad to which the probe needle which measures magnetic reluctance is dropped.

[0102] Many samples from which the combination of easy-axis lay length [of a sense line] L, die-length [of difficult shaft orientations] W, and die-length P of the magnetization fixed bed which exists in the perimeter differs were produced using the production approach mentioned above.
[0103] To the memory device produced through the above-mentioned process, the access signal was taken out and the component property was evaluated. 5mA of sense currents was caught with the oscilloscope by making resistance change of a sink and the magnetic-reluctance film into voltage variation. in order to eliminate the effect of the residual resistance in lead wire, or the contact resistance between pad probes -- electrical-potential-difference detection -- 4 terminal measuring methods -- using -- an electrical-potential-difference difference -- the difference of an oscilloscope -- it measured using the function. The square wave current signal of 1ms of periods was inputted into the word line (conductor line 51), and informational playback and record were performed by the synthetic field of the field generated according to a word line signal, and the generating field by the fixed sense current.
[0104] Drawing 8 is an example of a measurement wave of the voltage variation equivalent to the resistance change of a word line signal and the magnetic-reluctance film at the time of playback. The signal wave forms of "0" and "1" read on the conditions of 5mA of sense currents and 80mA of WORD currents are shown in drawing 8 (a) and (b) to L= 20 micrometers, W= 20 micrometers, P= 60 micrometers, and the component chosen as P/L=3, respectively. An upper case shows a sense electrical potential difference (equivalent to resistance change of the magnetic-reluctance film), and the lower berth shows time amount change of a WORD current. The WORD current is read with the current probe and a transform coefficient is 100mA = 10mV. "0" and "1" become identifiable from the zero level of the WORD current illustrated by "1->" among drawing 8 by the wave of a sense electrical potential difference changing according to recording information "0" and "1", and carrying out differential detection of the standup of a sense electrical potential difference only with the WORD current by the side of plus.
[0105] To two or more sorts of samples (memory device) from which L and P differ, only the current by the side of plus compares whether signal regeneration is possible, and the result is shown in Table 1. The above result shows that playback of a signal is possible for P/L only with the WORD current by the side of plus in 2.5 or more components. Therefore, playback of a signal is possible, without these P/L using a bipolar power supply with 2.5 or more samples.

[0106]
[Table 1]



[0107] (Example 2) Other examples of a configuration of MRAM of this invention in this example are shown in drawing 2 . With the component configuration of drawing 2 , the magnetization fixed bed of different lamination from this magnetic-reluctance film is prepared to the magnetic-reluctance film of the spin dependence dispersion mold by the field inner magnet-ized film. For 1, as for the 1st ferromagnetic layer and 12, a substrate and 11 are [a non-magnetic layer and 13] the 2nd ferromagnetic layer. 11, 12, and 13 are doubled and the magnetic-reluctance film 10 is formed. 41 -- a buffer layer and 51 -- a conductor -- a line is shown. a conductor -- a line 51 exists in right above [of the magnetic-reluctance film 10] through an insulating layer (not shown), and by drawing 2 , in order to make it legible, it is divided and displayed on 51a and 51b. The magnetization fixed beds 62 and 63 are formed in the direction of drawing X at the side attachment wall of the magnetic-reluctance film 10. the sense current and conductor with which informational record playback flows in the direction of an arrow head 100 to such a sample in order of the magnetization fixed bed 62, the magnetic-reluctance film 10, and the magnetization fixed bed 63 -- it is performed by the synthetic field in which the WORD current which flows in the direction of arrow heads 101a and 101b generates a line 51.
[0108] Except having changed the ingredient of the magnetization fixed bed into Co, the same ingredient as the memory device of an example 1 and thickness were chosen, and the memory device was produced combining spatter membrane formation and a lift-off process. Since it is the ingredient with which the ingredient of the magnetization fixed bed differs from the magnetic-reluctance film unlike the memory device of an example 1, it is necessary to increase the photolithography process for this magnetization fixed-bed formation once.
[0109] To two or more sorts of samples (memory device) from which L and

P differ, the sense current and the WORD current were impressed by the same technique as an example 1, record playback was performed, and it verified whether a signal would be refreshable only with the current by the side of plus. The result is shown in Table 2. By using Co of a ferromagnetic for the magnetization fixed bed, compared with the component using the magnetization fixed bed of the same lamination as the magnetic-reluctance film of an example 1, even if P/L was small, it was checked only with the WORD current by the side of plus that playback of a signal is possible. Therefore, die-length P of the magnetization fixed bed could be shortened, and it turned out that it is the structure where a higher degree of integration can be attained. It is possible to acquire a desired property by adjusting suitably the quality of the material used for the magnetization fixed bed and thickness.

[0110]

[Table 2]

[0111] (Example 3) Other examples of a configuration of MRAM of this invention in this example are shown in drawing 3 . The component configuration shown in drawing 3 is an example of component structure which prepared the magnetization fixed bed of the same lamination as this magnetic-reluctance film using the magnetic-reluctance film of the spin tunnel mold by the field inner magnet-ized film. As for the 1st ferromagnetic layer, and 12, 22 and 32, for 1, a non-magnetic layer, and 13, 23 and 33 are [a substrate, and 11, 21 and 31] the 2nd ferromagnetic layer. 11, 12, and 13 are doubled, the magnetic-reluctance film 10 doubles 21, 22, and 23, the magnetization fixed bed 20 doubles 31, 32, and 33, and the magnetization fixed bed 30 is formed. 71 and 72 -- a conductor -- a line is shown. a conductor -- a line 71 -- the 1st magnetic layer 11, 21, and 31 -- a conductor -- the line 72 is electrically connected to the 2nd magnetic film 13. furthermore, a conductor -- a line 72 top -- an insulator layer -- minding -- a conductor -- the word line is formed in the line 72 and this direction (un-illustrating). a conductor -- lines 71 and 72 work as a lower sense

line and an up sense line, respectively, and a sense current passes the magnetic-reluctance film 10 from a lower sense line, and flows to an up sense line. Informational record playback is performed by the synthetic field which the current which flows to a sense line and a word line generates.

[0112] A photolithography and lift off were used for processing of a component. Many samples which changed the die length of L, P1, and P2 about each width of face W were produced having set easy-axis X lay length of the magnetic-reluctance film to L, having set width of face to W, and having used X lay length of P1 and the magnetization fixed bed 30 (and magnetization fixed bed 20) as P2 for spacing of the direction of X of the magnetic-reluctance film 10 and the magnetization fixed bed 30 (and magnetization fixed bed 20).

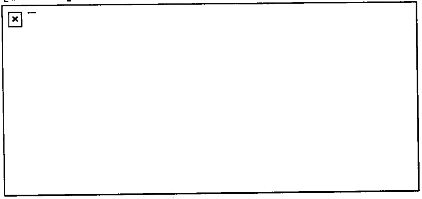
[0113] membrane formation of each ingredient film -- a sputtering system -- using -- 5x10 - 5 or less Pa of ultimate-pressure force -- a conductor -- aluminum of a line 71, nickel80Fe20 of the 1st magnetic layer 11, 21, and 31, AlOx of non-magnetic layers 12, 22, and 32, Co of the 2nd magnetic layer 13, 23, and 33, SiN of an insulator layer, and a conductor -- each film of aluminum of a line 72 was formed. thickness -- respectively -- a conductor -- aluminum of a line 71 -- nickel80Fe20 of 25nm and the 1st magnetic layer -- AlOx of 25nm and a non-magnetic layer -- Co of 1.2nm and the 2nd magnetic layer -- 25nm and a conductor -- SiN of 50nm and an insulator layer was set to 110nm for aluminum of a line 72. Here, nickel80Fe20 of the 1st magnetic layer is soft magnetic materials, and as a playback layer, Co of the 2nd magnetic layer is a hard magnetic material, and it functions as a memory layer. After carrying out the spatter of the aluminum at first, oxygen was introduced in equipment, it was left in production of AlOx which is a non-magnetic layer in 1000Pa for 125 minutes, and the AlOx oxide film was formed in it. Except for the oxygen introduced by carrying out evacuation to the predetermined ultimate-pressure force, the following Co film was formed after formation of the oxide film of this aluminum. At the time of membrane formation, the permanent magnet is arranged so that it may have the same magnetic anisotropy as the direction of a substrate front face. Magnetic field strength which a permanent magnet generates was set to 200e(s) focusing on measurement.

[0114] To two or more sorts of samples (memory device) from which L, P1, and P2 differ, the sense current and the WORD current were impressed by the same technique as an example 1, record playback was performed, and it verified whether a signal would be refreshable only with the current by the side of plus. The result is shown in Table 3. It checked that a

signal was refreshable only with the current by the side of plus because the configuration using the magnetic-reluctance film of a spin tunnel mold also forms the magnetization fixed beds 20 and 30 and makes P2/L 2.5 or more.

[0115]

[Table 3]



[0116] (Example 4) Other examples of a configuration of MRAM of this invention in this example are shown in drawing 4 . With the component configuration shown in drawing 4 , the magnetization fixed bed which consists of a different ingredient from this magnetic-reluctance film is prepared to the magnetic-reluctance film of the spin tunnel mold by the field inner magnet-ized film. For 1, as for the 1st ferromagnetic layer and 12, a substrate and 11 are [a non-magnetic layer and 13] the 2nd ferromagnetic layer. 11, 12, and 13 are doubled and the magnetic-reluctance film 10 is formed. The magnetization fixed beds 62 and 63 are formed in the direction of side-attachment-wall X of the magnetic-reluctance film. 71 and 72 -- a conductor -- a line is shown. a conductor -- a line 71 -- the 1st magnetic layer 11 -- a conductor -- the line 72 is electrically connected to the 2nd magnetic film 13. furthermore, a conductor -- a line 72 top -- an insulator layer -- minding -- a conductor -- the word line is formed in the line 72 and this direction (un-illustrating). a conductor -- lines 71 and 72 work as a lower sense line and an up sense line, respectively, and a sense current passes the magnetic-reluctance film 10 from a lower sense line, and flows to an up sense line. Informational record playback is performed by the synthetic field which the current which flows to a sense line and a word line generates.

[0117] A photolithography and lift off were used for processing of a component. Many samples which changed the die length of L, P1, and P2 about each width of face W were produced having set easy-axis X lay length of the magnetic-reluctance film to L, having set width of face to

W, and having used X lay length of P1 and the magnetization fixed bed 63 (and magnetization fixed bed 62) as P2 for spacing of the direction of X of the magnetic-reluctance film 10 and the magnetization fixed bed 63 (and magnetization fixed bed 62).

[0118] Except having changed the ingredient of the magnetization fixed bed into Co, the same ingredient as the memory device of an example 3 and thickness were chosen, and the memory device was produced combining spatter membrane formation and a lift-off process. Since it is the ingredient with which the ingredient of the magnetization fixed bed differs from the magnetic-reluctance film unlike the memory device of an example 3, it is necessary to increase the photolithography process for this magnetization fixed-bed formation once.

[0119] To two or more sorts of samples (memory device) from which L, P1, and P2 differ, the sense current and the WORD current were impressed by the same technique as an example 1, record playback was performed, and it verified whether a signal would be refreshable only with the current by the side of plus. The result is shown in Table 4. The magnetization fixed beds 62 and 63 were formed and it checked that a signal was refreshable only with the current by the side of plus by making P2/L or more into 1.5. Even if the die length P2 of the magnetization fixed bed is more small in this example which uses Co of a ferromagnetic for the magnetization fixed bed compared with the magnetization fixed bed and the component using the magnetization fixed bed of the same lamination as the magnetic-reluctance film of an example 3 when the spacing P1 of the magnetic-reluctance film is the same, it is checked only with the WORD current by the side of plus that playback of a signal is possible. Therefore, the distance between adjoining magnetic-reluctance film (P1+P2+P1) could be shortened, and it turned out that it is the structure where a higher degree of integration can be attained. It is possible to acquire a desired property by adjusting suitably the quality of the material used for the magnetization fixed bed and thickness.

[0120]

[Table 4]

[0121] (Example 5) Other examples of a configuration of MRAM of this invention in this example are shown in drawing 14 . Drawing 14 shows the example of the component structure which prepared the magnetization fixed bed of a configuration of that the magnetic films which form this magnetic-reluctance film differ to the magnetic-reluctance film of the spin tunnel mold which used perpendicular magnetic anisotropy films. For 1, as for the 1st ferromagnetic layer and 12, a substrate and 11 are [a non-magnetic layer and 13] the 2nd ferromagnetic layer. 11, 12, and 13 are doubled and the magnetic-reluctance film 10 is formed. On the 2nd [of this magnetic-reluctance film 10] ferromagnetic layer 13, it is superimposed on the magnetization fixed bed 62 and a non-magnetic layer 64. 71 and 72 -- a conductor -- a line is shown. a conductor -- a line 71 -- the 2nd magnetic layer 13 -- a conductor -- the line 72 is electrically connected to the magnetization fixed bed 62. furthermore, the side face of the magnetic-reluctance film 10 -- an insulator layer -- minding -- a conductor -- the conductor which functions in a line 72 and this direction as a word line -- the line 51 is formed. a conductor -- lines 71 and 72 work as a lower sense line and an up sense line, respectively, and a sense current passes the magnetic-reluctance film 10 from a lower sense line, and flows to an up sense line. Informational record playback is performed by the synthetic field which the current which flows to a sense line and a word line generates. The usual semi-conductor manufacture process was used for processing of a component.
[0122] membrane formation of each ingredient film -- a sputtering system -- using -- 5x10 - 5 or less Pa of ultimate-pressure force -- it is -- a conductor -- aluminum of a line 71, Gd21Fe79 of the 1st magnetic layer 11, AlOx of a non-magnetic layer 12, Gd21Fe79 of the 2nd magnetic layer 13, SiN of an insulator layer, and a conductor -- each film of Tb26Fe74 of aluminum of a line 72, Cu of a non-magnetic layer 64, and the magnetization fixed bed 62 was formed. thickness -- respectively -- a conductor -- aluminum of a line 71 -- Gd21Fe79 of 25nm and the 1st

magnetic layer 11 -- AlOx of 15nm and a non-magnetic layer 12 -- Gd21Fe79 of 2.2nm and the 2nd magnetic layer 13 -- 40nm and a conductor -- Tb26Fe74 of 5nm and the magnetization fixed bed 62 was set [aluminum of a line 72 / SiN of 50nm and an insulator layer] to 50nm for Cu of 60nm and a non-magnetic layer 64. Here, the 1st magnetic layer 11 functions as a playback layer, and the 2nd magnetic layer 13 functions as a memory layer. After carrying out the spatter of the aluminum at first, oxygen was introduced in equipment, it was left in production of AlOx which is a non-magnetic layer 12 in 1000Pa for 125 minutes, and the AlOx oxide film was formed in it. Except for the oxygen introduced by carrying out evacuation to the predetermined ultimate-pressure force, the Gd21Fe79 following film was formed after formation of the oxide film of this aluminum.
[0123] To two or more sorts of samples (memory device) from which L and W differ, the sense current and the WORD current were impressed by the same technique as an example 1, record playback was performed, and it verified whether a signal would be refreshable only with the current by the side of plus. The result at the time of considering as 1mA of sense currents is shown in Table 5. By forming the magnetization fixed bed 62, it checked that a signal was refreshable only with the current by the side of plus. The signal size at the time of making into 1mA of sense currents the result shown in Table 5 depending on the flat-surface configuration (area) of the magnetic-reluctance film means changing in inverse proportion to area.
[0124] Moreover, in this example, although the configuration which sandwiched Cu as a non-magnetic layer between the magnetization fixed bed and the magnetic-reluctance film is taken, by being prepared in order to control the magnitude of the field of the magnetization fixed bed in the magnetic-reluctance film, and choosing the ingredient of the magnetization fixed bed, and thickness suitably, the magnitude of the field of the magnetization fixed bed is adjusted and this non-magnetic layer can also exclude this non-magnetic layer.
[0125]
[Table 5]

[0126]

[Effect of the Invention] The effectiveness of this invention is preparing the magnetization fixed bed near the playback layer of MRAM, and is that playback becomes possible only by the pulse current by the side of plus or minus, without changing the direction of a seal of approval of the current which generates the current magnetic field at the time of reproducing a signal to positive/negative as stated above. For this reason, since signal detection just needs to supply the pulse current of one of positive/negative, in a playback special-purpose machine, unlike the conventional regenerative apparatus, the advantage from which a bipolar power supply becomes unnecessary is yielded, and the miniaturization of equipment is also attained. As a result, low cost-ization is attained and offer of a cheap memory apparatus and the non-volatile solid-state memory for them is attained.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the perspective view showing typically the example of a configuration of MRAM (spin dispersion mold) which prepared the magnetization fixed bed of the same layer structure as the magnetic-reluctance film of this invention.
[Drawing 2] It is the perspective view showing typically the example of a configuration of MRAM (spin dispersion mold) which prepared the magnetization fixed bed which consists of magnetic materials other than the spin dispersion film of the magnetic-reluctance film.
[Drawing 3] It is the perspective view showing typically the example of a configuration of MRAM (spin tunnel mold) which prepared the magnetization fixed bed of the same layer structure as the magnetic-reluctance film of this invention.
[Drawing 4] It is the perspective view showing typically the example of a configuration of MRAM (spin tunnel mold) of this invention using the magnetization fixed bed which consists of magnetic materials other than the spin tunnel film of the magnetic-reluctance film.
[Drawing 5] It is a mimetic diagram explaining the principle of operation of MRAM, and (a) is drawing where signal record and (d) - (g) explain the principle of operation of signal regeneration in the example of a configuration of MRAM (spin dispersion mold), (b), and (c).
[Drawing 6] It is the perspective view showing typically the flow

approach of the sense current in CIP structure and CPP structure.
[Drawing 7] the membrane formation process of the magnetic-reluctance film that are drawing explaining the production process of MRAM (spin dispersion mold) of an example 1, and (a) and (b) were patternized, (c), and (d) -- the membrane formation process of an insulator layer, (e), and (f) -- a conductor -- the membrane formation process of a line and the metal membrane for PURUBU pads is shown.
[Drawing 8] It is drawing showing an example of a signal wave form at the time of the playback in MRAM (spin dispersion mold) of an example 1, and a signal wave form [in / (a) and / in (b) / "1" condition] is shown. ["0" conditions]
[Drawing 9] It is drawing showing typically the magnetization condition in the current magnetic field H**0 in MRAM (spin dispersion mold) of an example 1, and (a) shows "0" conditions and (b) shows "1" condition.
[Drawing 10] It is the perspective view showing typically the configuration which array-ized MRAM of an example 4.
[Drawing 11] It is drawing showing typically the field-MR ratio minor loop in the conventional MRAM.
[Drawing 12] It is drawing of the field-MR ratio minor loop in MRAM of this invention shown typically.
[Drawing 13] It is the sectional view showing typically the configuration of MRAM of the spin tunnel structure by the perpendicular magnetic anisotropy films of this invention.
[Drawing 14] It is the perspective view which is an example of MRAM of the spin tunnel structure by the perpendicular magnetic anisotropy films of this invention and in which showing the configuration of MRAM of an example 5 typically.
[Description of Notations]
1 Substrate
10 Magnetic-Reluctance Film
11 1st Magnetic Layer
12 Non-magnetic Layer
13 2nd Magnetic Layer
20 Magnetization Fixed Bed
21 1st Magnetic Layer
22 Non-magnetic Layer
23 2nd Magnetic Layer
30 Magnetization Fixed Bed
31 1st Magnetic Layer
32 Non-magnetic Layer
33 2nd Magnetic Layer

41 Buffer Layer
51 Conductor -- Line
62 Magnetization Fixed Bed
63 Magnetization Fixed Bed
64 Non-magnetic Layer
71 Conductor -- Line
72 Conductor -- Line
100 Sense of Magnetization
101a Sense of a current
101b Sense of a current
102a Sense of the field to generate
102b Sense of the field to generate
102 Magnetic-Reluctance Film
103 Magnetic-Reluctance Film
202 Magnetic-Reluctance Film
203 Magnetic-Reluctance Film
302 Magnetic-Reluctance Film
303 Magnetic-Reluctance Film
623 Magnetization Fixed Bed
701 Conductor -- Line
702 Conductor -- Line

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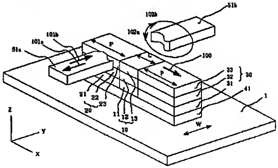
(54)【発明の名称】　磁気抵抗効果メモリ、および、それに記録される情報の再生方法とその再生装置

(57)【要約】
【課題】　正負の電流パルスを印加することなく再生可能なＭＲＡＭの提供、ならびに、正または負の電流パルスのみを用いて、このＭＲＡＭの情報を再生する方法とそれに用いる再生装置の提供。
【解決手段】　基板上に形成される第１磁性層／非磁性層／第２磁性層からなる磁気抵抗膜と、この磁気抵抗膜近傍に配置された情報記録用の導体線あるいは情報の記録・再生兼用の導体線と、磁気抵抗膜の近傍に磁化固定層を有する磁気抵抗効果メモリ。この磁化固定層によって、磁気抵抗膜の磁性層の一つである再生層の磁化方向を一方向に配向させ、電流磁界－ＭＲ比マイナーループの中心を変移させ、正または負の電流パルスのみで、情報の再生を可能とする。



【特許請求の範囲】
【請求項１】　基板上に形成される再生層／非磁性層／メモリ層からなる磁気抵抗膜と、前記再生層の磁化方向を磁気的結合力によって一方向に配向させる磁化固定層を有することを特徴とする磁気抵抗効果メモリ。
【請求項２】　前記磁気的結合力が交換結合力であることを特徴とする請求項１に記載の磁気抵抗効果メモリ。
【請求項３】　前記磁気的結合力が静磁結合力であることを特徴とする請求項１に記載の磁気抵抗効果メモリ。
【請求項４】　前記磁気抵抗膜に対し前記基板と反対側に導体線が配置されていることを特徴とする請求項１に記載の磁気抵抗効果メモリ。
【請求項５】　前記非磁性層が導体からなることを特徴とする請求項1に記載の磁気抵抗効果メモリ。
【請求項６】　前記非磁性層が絶縁体からなることを特徴とする請求項1に記載の磁気抵抗効果メモリ。
【請求項７】　前記磁化固定層が、前記磁気抵抗膜と同じ層構成を有することを特徴とする請求項１－６のいずれか１項に記載の磁気抵抗効果メモリ。
【請求項８】　前記磁化固定層が、前記磁気抵抗膜とは異なる層構成を有することを特徴とする請求項1－６のいずれか１項に記載の磁気抵抗効果メモリ。
【請求項９】　前記磁気抵抗膜の磁化方向が、概ね膜面に対し面内方向であることを特徴とする請求項1－８のいずれか１項に記載の磁気抵抗効果メモリ。
【請求項１０】　前記磁気抵抗膜の磁化容易軸方向の長さＬと磁化固定層の長さＰとが、Ｐ／Ｌ＞２．５の範囲に選択されていることを特徴とする請求項７に記載の磁気抵抗効果メモリ。
【請求項１１】　前記磁気抵抗膜の磁化方向が、概ね膜面に対し垂直方向であることを特徴とする請求項１－６または８のいずれか１項に記載の磁気抵抗効果メモリ。
【請求項１２】　前記磁気抵抗膜と前記磁化固定層との間に導電性を有する非磁性層を設けることを特徴とする請求項１１に記載の磁気抵抗効果メモリ。
【請求項１３】　請求項１に記載の磁気抵抗効果メモリに記録される情報を再生する際、前記磁気抵抗膜に一方向の電流磁界を印加し、磁気抵抗変化を検出することにより記録される情報の検知を行なうことを特徴とする再生方法。
【請求項１４】　磁性層／非磁性層／磁性層からなる磁気抵抗膜と、前記磁気抵抗膜近傍に配置される導体線と、前記磁気抵抗膜の一つの磁性層の磁化方向を一方向に配向させる磁化固定層とを有する磁気抵抗効果メモリにおいて、前記磁気抵抗膜の二つの磁性層を再生層ならびに情報を記録するメモリ層として用いて、前記導体線に電流を流し、前記メモリ層に記録されている情報の再生を行なう方法において、
前記導体線に正負いずれか一方向のみの電流を流し、前記磁気抵抗膜の領域に前記一方向の電流により磁場を発生させ、
前記再生層の磁化を前記一方向の電流により発生した磁場の方向に配向させ、
前記磁場が印加された状態における前記磁気抵抗膜の抵抗値と前記磁場が印加されていない状態における前記磁気抵抗膜の抵抗値との差異である磁気抵抗変化を検出して、
記録された情報の再生を行なうことを特徴とする再生方法。
【請求項１５】　前記磁場が印加されていない状態において、前記再生層の磁化が前記磁気抵抗膜の近傍に設けられた前記磁化固定層の磁化方向に配向されることを特徴とする請求項１４に記載の再生方法。
【請求項１６】　請求項１３または１４に記載する再生方法に従い、磁気抵抗効果メモリに記録される情報の再生を行なうために用いる一方向の電流を供給する手段と磁気抵抗変化を検出する手段とを具えることを特徴とする再生装置。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、磁気抵抗効果を利用したメモリに関する。さらに詳しくは、その再生時の消費電力が小さく、また、メモリ特性が向上し、周辺回路の高速化とともに好適なコンピュータペリフェラル向けの安価なメモリとして利用可能な磁気抵抗効果メモリとその再生方法、再生装置に関する。
【０００２】
【従来の技術】コンピュータや電子機器に利用されるメモリ素子においては、激しい技術開発競争が繰り広げられている。日進月歩のスピードで技術が進展し、様々な新しいメモリデバイスが提案されている。近年、非磁性層を強磁性層の間にはさみ込んだ磁気抵抗膜で巨大磁気抵抗効果（Giant Magneto Registance）が発見され、この現象を利用した磁気センサー、メモリ素子が注目を集めつつある。以下において磁気抵抗膜を利用したメモリ素子の総称をＭＲＡＭとする。
【０００３】ＭＲＡＭでは、二つの強磁性層とその間に挟んだ薄い非磁性層の三層構造が情報を記録する基本構造単位となる。非磁性層をはさみ込んだ、二つの強磁性層の間で、その磁化方向がそろっている場合と反平行な場合とでは、抵抗値が異なる現象を利用して、“０”、“１”の状態を記録する。
【０００４】記録されている情報を読み出す際には、書き込みの際より弱い交流磁場を印加して、一方の強磁性層だけ、その磁化方向の向きを変化させ、その際に抵抗値変化を測定して、“０”、“１”の状態を読み出す。
ＭＲＡＭは、情報が磁気的に記録されるため、放射線耐性に優れ、原理的に不揮発であり高速で書き込み回数の制限がない利点がある。既存の半導体技術を流用することで高密度記録が容易に行えるので、将来的にはＤＲ

ＡＭの置き換えが期待される。例えば、特開平０６－２４３６７３号公報には、メモリ素子として利用に関する提案がなされている。

【０００５】ＭＲＡＭの動作原理を以下に示す。図５（ａ）は、ＭＲＡＭの構成を示す図である。基板上に、第１磁性層１１、非磁性層１２、第２磁性層１３、絶縁層８０、書き込み線（ワード線）５１の順に積層する構成を有している。強磁性層と非磁性層の組み合わせからなる磁気抵抗膜部は多層構造でも良い。

【０００６】第１磁性層１１と第２磁性層１２、この二つの強磁性層は軟磁性材料と硬磁性材料の組み合わせからなっており、軟磁性材料が情報を読み出す再生層となり、硬磁性材料が情報を蓄積するメモリ層となる。図５（ａ）では、第１磁性層１１が軟磁性材料を用いた再生層、第２磁性層１３が硬磁性材料を用いたメモリ層となっている。基板と第１磁性層１１の間にＳｉＮやＴａ等のバッファー層を設けてもよい。

【０００７】ＭＲＡＭの記録動作は、書き込み線で発生する磁界でメモリ層となる第２磁性層１３の磁化の方向を変えることで行われる。

【０００８】図５（ｂ）は、“０”を書き込む場合を示している。書き込み線に対し、紙面に垂直方向に裏面から正面に向かって記録電流を流すと、矢印の方向に磁界が発生する。記録する場合は発生する磁界を大きくすることで、再生層である第１磁性層１１だけでなく、メモリ層である第２磁性層１３の磁化方向も紙面上で右向きに書き込まれる。この状態が“０”である。

【０００９】図５（ｃ）は、“1”を書き込む場合を示している。書き込み線に対し、紙面に垂直方向に正面から裏面に向かって記録電流を流すと、矢印の方向に磁界が発生する。記録する場合は発生する磁界を大きくすることで、再生層である第１磁性層１１だけでなく、メモリ層である第２磁性層１３の磁化方向も紙面上で左向きに書き込まれる。この状態が“１”である。

【００１０】一方、再生時には、書き込み線に記録時よりも弱い再生電流パルスを両方向に順番に流すことで再生層の磁化を反転させ、その時の抵抗変化を読み取ることで実現する。

【００１１】図５（ｄ）～（ｇ）は、再生動作を示す一連の図である。図５（ｂ）に示すように“０”が記録されている状態において、書き込み線に対し、図５（ｄ）には、初め紙面に垂直方向に正面から裏面に向かって再生電流を流し、図５（ｅ）には、次に逆向きの電流を流した場合における磁性層の磁化方向の変化がそれぞれ示されている。

【００１２】図５（ｄ）に示すように、初め、書き込み線に対し紙面に垂直方向に正面から裏面に向かって再生電流を流した時には、矢印の向きに小さな磁界が発生する。この磁界強度では再生層である第１磁性層１１は磁化が反転するが、メモリ層である第２磁性層１３の磁化は“０”の方向を保ったままである。図５（ｅ）に示すように、次に、書き込み線に対し紙面に垂直方向に裏面から正面に向かって再生電流を流した時には、矢印の向きに小さな磁界が発生する。この磁界強度では再生層である第１磁性層１１は磁化が再反転するが、メモリ層である第１磁性層１３の磁化は“０”の方向を保ったままである。

【００１３】二つの磁性層の磁化方向に注目すると、初めの紙面に垂直方向に正面から裏面に向かって再生電流を流した時には、第１磁性層１１と第２磁性層１３の磁化方向は反平行状態である。

【００１４】次に書き込み線に対し紙面に垂直方向に裏面から正面に向かって再生電流を流した時には、第１磁性層１１と第２磁性層１３の磁化方向は平行状態である。従って、二方向に電流パルスを流す間に書き込み線の抵抗変化は反平行状態の高抵抗から平行状態の低抵抗へと変化する。このような高抵抗から低抵抗に抵抗値が変化する状態が“０”であると読み取れる。

【００１５】一方、図５（ｃ）に示すように“１”が記録されている状態において、書き込み線に対し、図５（ｆ）には、初め紙面に垂直方向に正面から裏面に向かって再生電流を流し、図５（ｇ）には、次に逆向きの電流を流した場合における強磁性層の磁化方向の変化がそれぞれ示されている。

【００１６】図５（ｆ）に示すように、初め、書き込み線に対し紙面に垂直方向に正面から裏面に向かって再生電流を流した時には、矢印の向きに小さな磁界が発生する。この磁界では、再生層である第１磁性層１１は磁化方向が変化しないし、メモリ層である第２磁性層１３の磁化も“１”の方向を保ったままである。図５（ｇ）に示すように、次に、書き込み線に対し紙面に垂直方向に裏面から正面に向かって再生電流を流した時には、矢印の向きに小さな磁界が発生する。この磁界強度では、再生層である第１磁性層１１は磁化が反転するが、メモリ層である第２磁性層の磁化を変化させるには不十分であり“１”の方向を保ったままである。

【００１７】二つの磁性層の磁化方向に注目すると、書き込み線に対し、初め紙面に垂直方向に正面から裏面に向かって再生電流を流した時には第１磁性層１１と第２磁性層１３の磁化方向は平行状態である。次に、紙面に垂直方向に裏面から正面に向かって再生電流を流した時には、第１磁性層１１と第２磁性層１３の磁化方向は反平行状態である。従って、二方向に電流パルスを流す間に書き込み線の抵抗変化は平行状態の低抵抗から反平行状態の高抵抗へと変化する。このような低抵抗から高抵抗に抵抗値が変化する状態が“１”であると読み取れる。

【００１８】以上述べたように、弱い電流パルスを書き込み線に流したときの抵抗変化を読み取ることで記録されている情報が“０”か“１”かを識別することができ

る。この記録再生方法は、不揮発、非破壊で高速駆動が可能であることから理想的なメモリ特性が期待できる。前記再生時における磁気抵抗変化を電気的に検出する方法は各種提案されているが、大別すると抵抗値そのもので大小の比較をする絶対検出と、電流を二方向に振った際の抵抗変化が増加方向か減少方向かを判断する差動検出とに分けられる。

【００１９】上記の動作説明では書き込み線を使ったメモリの記録・再生方法について説明を行ったが、書き込み線はＭＲＡＭの構成要素としては必須ではない。構造によっては、強磁性層の磁化を反転させる磁界の発生には隣接する他の配線を流用することもできる。

【００２０】ＭＲＡＭの構成を用いる材料と磁気抵抗のメカニズムの観点から分類すると、中間層に金属非磁性層を用いたスピン散乱型、一方の強磁性層の磁化方向を反強磁性層で固定したスピンバルブ型、絶縁体非磁性層を用いたスピントンネル型、その他に、非磁性層中に磁性材料の微粒子を分散したグラニュラー型、ペロブスカイト酸化膜を用いたＣＭＲ（Colossal Magnetoresistance）型などがある。

【００２１】スピン散乱型では非磁性層をＣｕ等の金属層として、二つの磁性層間のスピン依存散乱によりＧＭＲが発現する。すなわち、磁性層の磁化の向きが平行な場合には、磁化と反対方向のスピンを持つ電子は散乱されるが、磁化と同じ向きのスピンを持つ電子は散乱されず、全体として抵抗が低くなる。逆に、磁性層の磁化の向きが反平行な場合には、磁化と同方向なスピンを持つ電子、反対方向のスピンを持つ電子のいずれも散乱されるため全体として抵抗が高くなる。そのＭＲ比は、室温で５～１０％程度が得られ、電流と磁化の方向で決まる異方性磁気抵抗効果よりは大きいが、スピントンネル型よりは小さい。

【００２２】スピンバルブ型は、原理的にはスピン散乱と同じだが、一方の強磁性層に反強磁性層を組み合わせることで磁化方向をピン止めしている点が異なる。もう一方の磁性層の磁化方向は自由に回転できる。磁化曲線を取ると磁化方向により非対称な形状となり、ゼロ磁界付近で低抵抗から高抵抗へと線形に変化するため微小磁気をセンシングする磁気センサーに適した構造となっている。現在では、ハードディスクの読み取りセンサーとして実用化されている。

【００２３】スピントンネル型では非磁性層を絶縁体として、絶縁体を電子がトンネリングして２つの磁性層間を移動し、スピン電子の状態密度の差に依存する形で磁気抵抗効果が発現する。すなわち、磁性層の磁化の向きが平行な場合には、アップスピンを持つ電子はもう一方の強磁性層の空いたアップスピンの状態に、ダウンスピンを持つ電子はもう一方の強磁性層の空いたダウンスピンの状態にトンネルできるため、スピン電子の状態密度の差が小さくなり抵抗が低くなる。逆に、磁性層の磁化の向きが反平行な場合には、アップスピンを持つ電子、ダウンスピンを持つ電子のいずれもトンネルできないためスピン電子の状態密度の差が大きくなり抵抗が高くなる。そのＭＲ比は、室温で１０％～３０％程度が得られ、スピン散乱型より大きい。ただし、絶縁体をはさんだ構造のため、素子抵抗自体はスピン散乱型より大きい。このスピントンネル現象を利用しながら、反強磁性膜を使いスピンバルブ型とした磁気抵抗膜の研究が、次世代のハードディスク読み取りセンサー用として盛んに研究されている。

【００２４】グラニュラー型には、非磁性層として金属を用いたスピン散乱タイプと、絶縁体を用いたスピントンネルタイプの二種が存在する。先述したスピン散乱型やスピントンネル型では、各層ごとに役割分担を明確化しているのに対し、グラニュラー型では、マトリクス中に分散した個々の微細磁性粒子のスピンに依存する形でＧＭＲを発現する点が大きな相違である。Ｃｏ／ＡｌＯｘ系のスピントンネルタイプにおいて、８％程度のＭＲ比が室温で得られている。

【００２５】ＣＭＲ型では、ペロブスカイト構造のＭｎ酸化物をスピン分極率のより高いペロブスカイトＭｎ酸化物で挟み込んだトンネル接合とするタイプや、ペロブスカイト中の層状構造をトンネル接合として利用するタイプなどが存在する。ＣＭＲ型のスピン分極率は非常に高いため、極低温では４００％ものＭＲ比が得られる。

【００２６】ＭＲＡＭに使われる磁性材料を磁化方向で分類すると、膜面に平行な磁化成分を持つ面内磁化膜型と、膜面に垂直な磁化成分を持つ垂直磁化膜型とに分けられる。ＮｉＦｅ，Ｃｏ等の強磁性体は、磁化方向が膜面に平行な面内磁化膜型であるが、この面内磁化膜では磁性体の微細化が進むと磁極同士が近づいて反磁界が大きくなるため、磁化のカーリング現象が起きるという問題がある。カーリングが発生すると、磁化の方向を判別することが困難になる。そのため、面内磁化膜を用いたＭＲＡＭでは形状異方性をつけるため、メモリセルとなる強磁性層を平面的に見て長軸を持つ形状（長方形など）とする必要がある。長方形の長軸と短軸の比は、少なくとも２倍以上必要だと予想される。従って、カーリング現象防止のために、メモリセルのサイズが制約を受け、集積度向上の阻害要因となる。

【００２７】一方、強磁性層としてＴｂＦｅ，ＴｂＦｅＣｏ，ＧｄＦｅ等の希土類－遷移金属からなるフェリ磁性体を用いる場合、これら磁性体の垂直磁気異方性が高いため、膜厚と組成によっては、磁化を膜面に対し垂直方向に持つ垂直磁化膜となる。垂直磁化膜の場合には、磁化の方向は、形状的に最も反磁界が大きい膜面垂直方向を向いており、垂直磁気異方性を示す時点で既に最大の反磁界係数に打ち勝っていることになる。つまり、面内磁化膜のようにメモリセルを長方形とする必要がなく、メモリセルの平面形状を正方形とすることができ

る。さらに、素子を微細化すると、磁化容易軸である膜厚方向と比べ、平面的な面積が小さくなるので、形状異方性の観点では、磁化のカーリングがより起きにくい方向になる。そのため、垂直磁化膜型は、メモリセル部の集積度を向上する上では、面内磁化膜型と比べ有利である。

【００２８】ＭＲＡＭに対する電流の流し方、あるいは電極の配置の仕方により、電流の方向が膜面に対し、平行なＣＩＰ（Current In Plane）と、垂直なＣＰＰ(CurrentPerpendicular to the Plane)とに大別される。図６に、それぞれの電極構造を示す。

【００２９】図６（ａ）に示すように、ＣＩＰは、第1磁性層／非磁性層／第2磁性層からなるメモリセルの両側面にセンス層がついた構造であり、センス電流は膜面に平行に流れる。図６（ａ）中、センス層の一方は点線で図示している。ＣＩＰでは、スピン散乱型の磁気抵抗膜を用いる。その場合、１セルの抵抗はシート抵抗で１０Ω程度、センス線のシート抵抗は０．０５Ωとなる。また、磁気抵抗変化率は５～１０％程度とスピントンネル型と比較して小さい。ＣＩＰ構造で多数のセルをセンス線に直列接続して、その両端で信号検出する場合、繋がっている多数セルの抵抗値を合算した合成抵抗に対して、１つのセル分の抵抗変化を信号とするため、高いＳＮを達成するのは容易ではない。

【００３０】図６（ｂ）に示すように、ＣＰＰは、第１磁性層／非磁性層／第２磁性層からなるメモリセルの上下にセンス線がついた構造である。センス電流は、上下のセンス線間を、膜面に垂直方向に流れる。図６（ｂ）中、上部センス層は点線で示している。ＣＰＰでは、スピントンネル型の磁気抵抗膜を用いるのが良く、その場合、１セルの抵抗は数ｋΩから数十ｋΩ程度の範囲であり、センス線に比べて抵抗値が大きい。また、磁気抵抗変化率も１０～３０％程度となり、スピン散乱型と比較して大きい。すなわち、磁気抵抗膜をセンス線に接続しても十分大きな抵抗変化が得られ、よって高いＳＮが得られる。

【００３１】このＣＰＰ構造ではセンス線の交差点にセルを配置するため、セルを多数配置する場合、各々のセルは並列に接続される。この構成では、特定のセルの抵抗を検出する場合、そのセルに交差するセンス線に電流を流すことにより、他のセルの影響をあまり受けずに検出を行うことができるため、ＣＩＰ構造と比べＳＮは高くなる。従って、ＣＩＰ構造と比べ、ＣＰＰ構造の方が1列のセンス線に接続可能なセル数が多く大規模なマトリクスを容易に形成することができる。つまりメモリ素子として多数のメモリセルを並べて駆動することを考えた場合には、ＣＩＰ構造よりＣＰＰ構造の方が有利である。

【００３２】

【発明が解決しようとする課題】ＭＲＡＭにおいて差動検出を利用する際には、正負の電流を交互に流した時の抵抗変化を微分検出することで”０”か”１”を識別する。正負の電流を発生するためにはバイポーラ電源が必要となる。高速のバイポーラ機能を実現する上では、電流の向きを反転させるために幾つかのスイッチを高速に正確なタイミングで切り替えることが重要である。タイミングにずれが生じると電流波形にリンギングやオーバーシュートが起きる。これらは誤動作の原因となるため極力抑制しなければならない。リンギングやオーバーシュートを抑制するためには遅延要素となる配線容量や負荷抵抗等を考慮した電源回路の最適化が不可欠で、スイッチング機能実現のためのトランジスタ増設と併せ電源回路の占めるスペースが増大しメモリとしての集積度を向上する上で問題となる。集積度を向上させる弊害となるためメモリのビット当たり単価を高くする要因ともなる。

【００３３】最近、固体メモリの利用分野としてテープ媒体を利用したウオークマンタイプのヘッドホンステレオに代わりＭＰ３プレーヤーが注目されている。ＭＰ３プレーヤーに応用すると耐震性、耐久性、小型化等の観点で固体メモリの利点がフルに発揮される。加えて、機械的な駆動部分を必要とせず、低消費電力の利点も生かせる。また、ＣＤ、ＭＤなどで供給されている再生専用のソースに代えて、固体メモリを用いた再生専用のソースの供給がなされると想定される。

【００３４】ＭＲＡＭも、こうした再生専用ニーズに利用する場合が相当数あると考えられるが、その普及を図る際、上述するような再生に用いる専用バイポーラ電源のスペース・コストは無視できないものとなる。

【００３５】ＭＲＡＭの信号再生が、正負いずれか一方の電流パルスを流すことで実現できれば上記の問題は解決する。再生を行う際に導体線に加える電源回路にバイポーラ機能が不要になれば回路構成を単純化でき、加えて製造コストも下がる。また、集積度向上の制約がなくなり、ビット当たり単価の低減を容易に進めることが可能となる。このような要望はあるものの正負いずれか一方の電流を使っての信号再生は実現されていなかった。

【００３６】本発明は前記の課題を解決するもので、本発明の目的は、正負の電流パルスを印加することなく再生可能なＭＲＡＭの提供、ならびに、正または負の電流パルスのみを用いて、このＭＲＡＭの情報を再生する方法とそれに用いる再生装置を提供することにある。それにより、ＭＲＡＭ特性を向上し、周辺回路の高速化と共により好適なコンピュータペリフェラル向けの安価なメモリを実現することを目的とする。

【００３７】

【課題を解決するための手段】本発明者らは、上記課題に解決すべく鋭意研究をした結果、正負の電流パルスを印加することなく再生可能なＭＲＡＭを作製し、それにより、ＭＲＡＭ特性を向上し、周辺回路の高速化と共に

より好適なコンピュータペリフェラル向けの安価なメモリを実現可能とした。すなわち、本発明は、下記する（１）～（１２）の各項に記載する構成を有する磁気抵抗効果メモリ、また、（１３）～（１５）の各項に記載する、かかる磁気抵抗効果メモリに記録される情報の再生方法、ならびに（１６）項に示す再生装置である。

【００３８】（１）　基板上に形成される第１磁性層／非磁性層／第２磁性層からなる磁気抵抗膜と、前記第１磁性層もしくは第２磁性層の磁化方向を磁気的結合力によって一方向に配向させる磁化固定層とを有することを特徴とする磁気抵抗効果メモリ。

【００３９】（２）　前記磁気的結合力が交換結合力であることを特徴とする項（１）に記載の磁気抵抗効果メモリ。

【００４０】（３）　前記磁気的結合力が静磁結合力であることを特徴とする項（１）に記載の磁気抵抗効果メモリ。

【００４１】（４）　前記磁気抵抗膜に対し前記基板と反対側に導体線が配置されていることを特徴とする項（１）に記載の磁気抵抗効果メモリ。

【００４２】（５）　前記非磁性層が導体からなることを特徴とする項（１）に記載の磁気抵抗効果メモリ。

【００４３】（６）　前記非磁性層が絶縁体からなることを特徴とする項（１）に記載の磁気抵抗効果メモリ。

【００４４】（７）　前記磁化固定層が、前記磁気抵抗膜と同じ層構成を有することを特徴とする項（１）－（６）のいずれか１項に記載の磁気抵抗効果メモリ。

【００４５】（８）　前記磁化固定層が、前記磁気抵抗膜とは異なる層構成を有することを特徴とする項 (1)－（６）のいずれか１項に記載の磁気抵抗効果メモリ。

【００４６】（９）　前記磁気抵抗膜の磁化方向が、概ね膜面に対し面内方向であることを特徴とする項 (1)－（８）のいずれか１項に記載の磁気抵抗効果メモリ。

【００４７】（１０）　前記磁気抵抗膜の磁化容易軸方向の長さＬと磁化固定層の長さＰとが、Ｐ／Ｌ＞２．５の範囲に選択されていることを特徴とする項（７）に記載の磁気抵抗効果メモリ。

【００４８】（１１）　前記磁気抵抗膜の磁化方向が、概ね膜面に対し垂直方向であることを特徴とする項（１）－（６）または（８）のいずれか１項に記載の磁気抵抗効果メモリ。

【００４９】（１２）　前記磁気抵抗膜と前記磁化固定層との間に導電性を有する非磁性層を設けたことを特徴とする項（１１）に記載の磁気抵抗効果メモリ。

【００５０】（１３）　項（１）に記載の磁気抵抗効果メモリに記録される情報を再生する際、前記磁気抵抗膜に対して一方向の電流磁界を印加し、磁気抵抗変化を検出することにより記録される情報の検知を行なうことを特徴とする再生方法。

【００５１】（１４）　磁性層／非磁性層／磁性層からなる磁気抵抗膜と、前記磁気抵抗膜近傍に配置される導体線と、前記磁気抵抗膜の一つの磁性層の磁化方向を一方向に配向させる磁化固定層とを有する磁気抵抗効果メモリにおいて、前記磁気抵抗膜の二つの磁性層を再生層ならびに情報を記録するメモリ層として用いて、前記導体線に電流を流し、前記メモリ層に記録されている情報の再生を行なう方法において、前記導体線に正負いずれか一方向のみの電流を流し、前記磁気抵抗膜の領域に前記一方向の電流による一方向の電流磁場を発生させ、前記再生層の磁化を前記一方向の電流により発生した磁場の方向に配向させ、前記磁場が印加された状態における前記磁気抵抗膜の抵抗値と前記磁場が印加されていない状態における前記磁気抵抗膜の抵抗値との差異である磁気抵抗変化を検出して、記録された情報の再生を行なうことを特徴とする再生方法。

【００５２】（１５）　前記磁場が印加されていない状態において、前記再生層の磁化が前記磁気抵抗膜の近傍に設けられた前記磁化固定層の磁化方向に配向されることを特徴とする項（１２）に記載の再生方法。

【００５３】（１６）　項（１３）、（１４）または（１５）のいずれか１項に記載する再生方法に従い、磁気抵抗効果メモリに記録される情報の再生を行なうために用いる一方向の電流を供給する手段と磁気抵抗変化を検出する手段とを具えることを特徴とする再生装置。

【００５４】

【発明の実施の形態】本発明のＭＲＡＭにおいては、従来は、記録情報の再生時にワード線に流す電流をパルス的に電流の印加方向を正負に切り替える手段を用いているが、それに代えて、再生層の磁化反転に、磁化固定層と、磁気抵抗膜近傍に配置される導体線にプラス側もしくはマイナス側のパルス電流のみを印加する手段とを組み合わせている。

【００５５】以下図面を用いて、この本発明のＭＲＡＭについて、その構成ならびに記録情報の再生方法についてより詳しく説明する。

【００５６】まず磁化固定層とは、磁気抵抗膜の近傍に配置されるものであり、予め磁界をかけ一方向に配向させた磁性層である。この磁化固定層の機能は、外部磁界を取り去っても所望の保磁力で磁化を有する状況を作り出すことである。磁化固定層の材質や膜厚は、磁気抵抗膜の性質によって適宜選択されるものであり、上述の機能を果たすならば、以下の実施例の構成に限られるものではない。

【００５７】磁化固定層は、メモリセルとなる磁気抵抗膜1組に対し空間的近傍に配置するものである。機能は、磁気抵抗膜を構成する磁性膜の磁化容易軸方向に磁界を印加するものであり、あらかじめ外部から磁界をかけて設定した初期化磁界を保持し、信号を再生する電流発生磁場が近似的にゼロの時、再生層となる第1磁性層の磁化方向を一定に保つものである。このため、再生電

流発生磁場が近似的にゼロの時点で、第１磁性層と第２磁性層の磁化方向の関係が平行か反平行かを識別できることになる。つまり、正負いずれか一方の電流を印加することで信号を検出できる。一本の導体線に流す電流の二方向のうち、どちらを正（プラス）とするか、負（マイナス）とするかは任意に決定できる。

【００５８】この磁化固定層の作製には種々の方法がある。メモリセルを作製する際に、成膜した磁気抵抗膜の一部を磁化固定層として流用することができる。また、メモリセルの磁気抵抗膜とは別に異なる磁性材料を成膜して、メモリセルに隣接する位置に磁化固定層を設けても良い。この磁化固定層の機能を有する手段としては、例えば特開平１０－３１２５１４号公報などにおいて開示されているハードディスク記憶装置用の磁気ヘッドにおけるバイアス磁界印加手段を用いてもよい。

【００５９】磁化固定層に面内磁化膜のスピン散乱膜を用いる場合を例にとり、本発明の作用を説明する。図１に、メモリセルの構成の一例を示す。１は基板、１１、２１、３１は第1の強磁性層、１２、２２、３２は非磁性層、１３、２３、３３は第２の強磁性層である。１１、１２、１３を合わせて磁気抵抗膜１０が、２１、２２、２３を合わせて磁化固定層２０が、３１、３２、３３を合わせて磁化固定層３０が形成されている。４１はバッファ層、５１は導体線を示す。導体線５１は磁気抵抗膜１０の直上に絶縁層（図示しない）を介して存在し、図1では見易くするため５１aと５１bに分割して表示している。

【００６０】情報の記録・再生時には矢印１００の方向に磁化固定層２０、磁気抵抗膜１０、磁化固定層３０の順にセンス電流が流され、導体線５１には矢印１０１ａ、１０１ｂの方向にワード電流が流される。磁化固定層２０の第１の強磁性層２１と、磁化固定層３０の第１の強磁性層３１は、ともに面内一定方向に磁化されており、その磁化の向きに従って、磁気抵抗膜１０の第１の強磁性層１１は、その磁化が配向する。情報の記録・再生は、センス電流ならびにワード電流の発生する合成磁界によって、磁気抵抗膜１０の第１強磁性層１１の磁化方向を変化させることで行われる。

【００６１】図１に示す面内磁化膜を用いた磁気抵抗膜１０の、メモリセルとなるセンス線方向の長さをL，幅をW、磁化固定層の長さをＰとする。Ｐは、多数のメモリセルが並ぶ場合、次のメモリセルとの間隔に相当する。

【００６２】ここで、Ｐ／Ｌ＞２．５の範囲に選択するとワード電流を正負の双方向に振らなくても、あらかじめ外部磁界を印加して設定した初期化磁化方向と反対の磁界を発生する正または負電流パルスのみで信号の再生ができる。すなわち、磁気抵抗膜１０の第1磁性層１１は初期化磁化方向を向いた磁化固定層２０及び３０に取り囲まれているため、この両者の磁化方向と同じ方向に従う傾向が強い。例えば、前記の初期化磁化方向が“１”の信号を書き込んだ第２の強磁性層（メモリ層）に対し反平行である時、ワード電流がゼロとなり、磁気抵抗膜１０の第１磁性層１１（再生層）に印加される電流磁場がほぼゼロになると、反平行な状態で安定することになる。

【００６３】従って、初期化磁化方向と反対の磁界を発生する電流パルスの有無で“０”の場合は高抵抗から低抵抗へ、“１”の場合は低抵抗から高抵抗へ変化する。この変化を微分検出すれば高速に“０”と“１”の識別が可能である。

【００６４】図１のように、面内磁化膜型のスピン散乱膜を磁化固定層とする場合、Ｐ／Ｌは２．５より大きいことが必要だが、過大になると信号を記録する際に大きな電流が必要となったり、信号再生マージンが小さくなるという問題が起きる。また、集積度の観点からも小さい方が望ましい。従って、Ｐ／Ｌは５０以下とし、より望ましくは、２．５～１０の範囲に選択すると良い。

【００６５】ＬとＰは、本発明の正負いずれか一方のパルス電流のみを用いる再生方法において、その再生に要する電流量に密接に関係するが、Wは大きくは関わらない。ただし、Wが小さくなると磁化方向はＬに平行な成分に限定されるようになるため、再生時における磁化反転のエネルギーが増え、信号再生に必要なワード電流が増える傾向にある。

【００６６】この現象に関して図1を用いてさらに詳述する。メモリアレイ全体に対しあらかじめ外部磁界を印加して設定した初期化磁化方向を－Ｘ方向とする。従って、何も電流を流さない場合の磁気抵抗膜１０、磁化固定層２０、３０の磁化方向は－Ｘ方向である。実際にはセンス電流とワード電流による合成磁界でＸＹ平面上に磁化方向が決まるが、説明を簡略化するためセンス電流が発生する磁界の影響は考えないことにすると、メモリセルの磁化方向は導体線５１を流れるワード電流の発生磁界方向１０２ａ，１０２ｂと磁界の大きさによって±Ｘ方向に決められる。

【００６７】まず、初めに、従来の再生方法である正負の電流を流す場合を考える。矢印１０１aの方向にワード電流を流すと発生する磁界は矢印１０２ａの方向になる。第1磁性層１１の保磁力より強い磁界を発生すると第1磁性層１１の磁化が矢印１０２ａの方向を向く。第1磁性層１１は導体線５１の下に位置するため、その磁化方向は＋Ｘ方向である。次に矢印１０１ｂの方向にワード電流を流すと矢印１０２ｂの方向に磁界が反転し、第1磁性層１１の磁化方向は－Ｘ方向になる。第２磁性層１３の磁化方向は初期化磁化方向とした－Ｘ方向のままであるから、ワード電流の変化に応じて第1磁性層と第２磁性層の磁化方向の関係は反平行から平行へと変化する。従って、＋Ｘ方向、次に－Ｘ方向の磁界を発生するワード電流に合わせて観察される抵抗変化は高抵抗から

低抵抗への変化となる。これが“０”の状態である。

【００６８】“１”の場合は、“０”と同様に矢印１０１ａ，１０１ｂの順にワード電流を流すと、発生する磁界は矢印１０２ａ，１０２ｂの順に変化し、第1磁性層１１の磁化方向は＋Ｘから－Ｘ方向へと変化する。第２磁性層１３の磁化方向は“１”では＋Ｘ方向であるから、ワード電流の変化に応じて磁性層と第２磁性層の磁化方向の関係は平行から反平行へと変化する。従って、観察される抵抗変化は＋Ｘ方向、次に－Ｘ方向の磁界を発生する電流に合わせ低抵抗から高抵抗への変化となる。これが”１”の状態である。

【００６９】次に、本発明の再生方法、すなわち、正負いずれか一方のパルス電流による再生について説明する。ワード電流を正負に振らなくても、初期化磁化方向と反対の磁界を発生する電流パルスで信号が検出できることから、＋Ｘ方向の磁界を発生させるワード電流を流せばよい。それは図1において磁界の向きでいえば矢印１０２aであり、ワード電流では矢印１０１aの方向である。

【００７０】“０”の場合、第２磁性層１３の磁化方向は－Ｘ方向である。矢印１０１a方向にワード電流を流すと＋Ｘ方向に第1磁性層１１の磁化が向く。一方、ワード電流１０１aを流さない場合は第1磁性層１１の磁化方向は周囲を取り囲む磁化固定層２０、３０の磁化方向が－Ｘ方向であるため、両隣の磁化固定層２１、３１と同じ－Ｘ方向である。従って、“０”の時は、ワード電流の有無で高抵抗から低抵抗になる。これは、“０”を表す。

【００７１】“１”の場合、第２磁性層１３の磁化方向は＋Ｘ方向である。矢印１０１a方向にワード電流を流すと＋Ｘ方向に第1磁性層１１の磁化が向く。一方、ワード電流１０１aを流さない場合は第1磁性層１１の磁化方向は両隣の磁化固定層２１、３１と同じ－Ｘ方向である。これは、周囲を取り囲む磁化固定層２０、３０の磁気的結合が＋Ｘ方向を向いた第２磁性層１３より強いためである。従って、“１”の時は、ワード電流の有無で低抵抗から高抵抗になる。これは、“１”を表す。

【００７２】つまり、通常の再生方法では正負の二つの電流パルスを印加して、第１磁性層１１の磁化方向を反転させているが、本発明の再生方法では正又は負の電流パルスで一時的に反転されている第１磁性層１１の磁化方向を、上記の磁化固定層の作用で元に復元することで、”０”と“１”の信号を読み取れることになる。

【００７３】本発明のＭＲＡＭにおける再生方法と磁化固定層を設けない従来のＭＲＡＭにおける再生方法との差異を磁界－ＭＲ比のマイナーループ図を使ってさらに詳細に説明する。図１１は、磁化固定層を設けない場合のマイナーループで、従来の再生方法に相当する。図１１（ａ）は“０”、図１１（ｂ）は“１”を第２磁性層１３に記録した状態に相当する。ここで、再生時に加わる磁界強度幅±Ｈは第１磁性層１１の保磁力より大きいが、第２磁性層１３の保磁力より小さなレベルである。なお、図中両端には、前記の磁界強度±Ｈ最大値における各磁性層の磁化状態を矢印で模式的に示す図を付記してある。また、メモリの各層を記号により示してある。マイナーループには同じく矢印にてヒステリシスの進路方向を表記した。図１１（ａ）の“０”に対して、＋Ｈ磁界を印加すると第１磁性層１１の磁化が反転して両磁性層の磁化方向が反平行になった高抵抗状態（ＭＲ大）になる。ここからゼロ磁界へ戻しても残留磁化が残るため、反平行な状態が保たれる。平行な低抵抗状態（ＭＲ小）へ戻すには、－Ｈ方向へ磁界を発生させる必要がある。一方、第２磁性層１３に“１”が記録された状態を考えると、図１１（ｂ）に示す通り、－Ｈ磁界を印加すると第１磁性層１１の磁化が反転し、両磁性層の磁化方向は反平行となるが、その後、平行な状態に戻すためには＋Ｈ方向の磁界を印加する必要がある。つまり、従来のＭＲＡＭは、再生の際に正負双方の電流パルスを用いて±Ｈ両方向の磁界を発生させないと、磁気抵抗信号の立ち上がり変化が“０”と”１”で逆転している現象を確認することができないものであった。

【００７４】図１２に、磁化固定層を設ける本発明のＭＲＡＭにおける再生時の磁界－ＭＲ比のマイナーループを示す。＋Ｈ方向の磁界を発生させる際、図１に示すＭＲＡＭでは導体線に矢印101a方向の電流を流す。図１２（ａ）は“０”、図１２（ｂ）は“１”を第２磁性層１３に記録した状態に相当する。また、図中両端には、前記の磁界強度±Ｈ最大値における各磁性層の磁化状態を矢印で模式的に示す図を付記してある。また、メモリの各層を記号により示してある。マイナーループには同じく矢印にてヒステリシスの進路方向を表記した。本発明のＭＲＡＭのマイナーループでは、磁化固定層２０（２１、２２、２３）と３０（３１、３２、３３）の効果により図１１と比べ＋Ｈ方向にシフトする。具体的には、ヒステリシスの中心（図中、点線で示す）が、矢印で示すシフト量＋Ｈ方向に偏移している。それに伴い、一旦＋Ｈ方向の磁界印加した後、ゼロ磁界に戻すと、磁化固定層の磁化の作用により第１磁性層１１の磁化は元の状態に戻る。すなわち、 第２磁性層１３に“０”が記録された状態では（図１２（ａ））、＋Ｈ磁界を印加した後、ゼロ磁界に戻すと、高抵抗から低抵抗（ＭＲ大→小）に変化する。第２磁性層１３に“１” が記録された状態では（図１２（ｂ））、＋Ｈ磁界を印加した後、ゼロ磁界に戻すと、低抵抗から高抵抗（ＭＲ小→大）に変化する。従って、＋Ｈ方向の磁界を発生する電流パルスのみで、“０”、“１”で信号の立ち上がり方が反転する現象の確認、すなわち記録信号の再生が可能になる。

【００７５】図9は、図１に示す構成の本発明のＭＲＡＭにおいて、ワード電流による電流発生磁場を近似的に

ゼロとした時の第１磁性層、第２磁性層の磁化状態を模式的に示す断面図である。図９（ａ）は第２磁性層１３に“０”を記録した状態を、図９（ｂ）は“１”を記録した状態をそれぞれ示している。第1磁性層１１の磁化方向はいずれも左右から挟む磁化固定層２０、３０と同じ初期化磁化方向を向いている。この状態から、紙面に対し裏面から表面に向かうパルス状のワード電流を印加すると、その間だけ、第１磁性層１１の磁化方向が反転するので、信号再生が可能になる。

【００７６】この磁化固定層は図１に示すスピン散乱膜に限られるものではなく、図２の様に磁気抵抗膜とは異なる磁性材料による磁化固定層６２、６３を用いることも可能である。このような磁気抵抗膜と異なる層構成の磁化固定層を用いる場合には、スピン散乱膜を使う場合と比べ、Ｐの間隔を詰めることができる。この場合は、Ｐの長さのスピン散乱膜による磁化固定層２０、３０と同じ磁化をより少ない体積で有する磁性材料に置き換えることでＰを短くすることができ、集積度を向上することが可能である。磁化固定層の長さＰと磁気抵抗膜の長さＬの関係は、用いる磁性材料や層構成等により、再生の際に用いる正負いずれかのパルス状電流値に応じて適宜調整すれば良い。

【００７７】上記の実施形態においては、磁気抵抗膜と磁化固定層が極近傍に接して設けられており、その際の磁気的結合力は交換結合力が支配的になっている。

【００７８】以上説明した磁化固定層の作用･機能は、スピン散乱膜に限定されるものではなく他の種類のＭＲＡＭに適用した際にも原理的に同じ作用が得られる。例えば、メモリセル構造に面内磁化膜のスピントンネル膜を用いた場合には、図１に示すスピン散乱膜の場合と同様に、図３のようにセンス線の磁化容易軸方向に連続的にスピントンネル膜を残すことで磁化固定層２０、３０として使うことができる。この場合は、電流が隣接メモリセルに流入するのを防ぐためスペースＰ１をあけて磁化固定層を設けることが必要である。また、磁化固定層はスピントンネル膜を用いなくても、図４の様に磁気抵抗膜とは異なる磁性材料による磁化固定層６２、６３を設けてもよい。その際には、図３に示されている長さＰ２のスピントンネル膜を用いる磁化固定層２０、３０と同じ作用を、より少ない体積で達成する磁性材料に置き換えることで、長さＰ２を短くすることができる。それにより、隣接するメモリセルとの間隔（Ｐ１＋Ｐ２＋Ｐ１）を狭くすることができ、集積度をさらに高めることが可能となる。磁気抵抗膜にスピントンネル膜を用いる構成においても、間隔Ｐ１、磁化固定層の長さＰ２と磁気抵抗膜の長さＬの関係は、用いる磁性材料や層構成などにより、再生の際に用いる正負いずれかのパルス状電流値に応じて、適宜調整すれば良い。なお、間隔Ｐ１を大きくすると磁化固定層の効果が達成されないため、通常Ｐ２＞＞Ｐ１となっている。従って、スピン散乱型における磁化固定層の長さＰと同様に、スピントンネル型でも磁化固定層の長さＰ２が実質的に隣接するメモリセルとの間隔に相当する。

【００７９】前記の実施形態においては、磁気的結合力は磁気抵抗膜と磁化固定層の位置関係から静磁結合力が支配的に働いている。

【００８０】メモリセルをマトリックス状に配置する際には、磁化固定層は、一つのメモリセルに対してのみ働くものではなく、隣接するメモリセルに対しても同様の効果をもたらす。図１０は、スピントンネル膜に別の磁性材料による磁化固定層を設けた他の一例であり、磁気抵抗膜を３×３にメモリアレイ化した構成例を表す。図面上、説明に用いない構成部品に関する符号、名称の表示は省略する。また、説明の都合上、可視化を図る必要があるので、磁気抵抗膜１０３、２０３、３０３上に位置する導体線は省略してある。本来は、磁気抵抗膜１０３、２０３、３０３上にも導体線が導体線７０１、７０２と平行に配置されている。例えば、磁化固定層６２３によって、主に磁気抵抗膜２０３と２０２の双方に対してその磁化方向を固定する。さらには、弱いながらも、その周囲にある磁気抵抗膜１０２、１０３、３０２、３０３に対しても、その磁化方向を固定する作用をもっている。

【００８１】本発明のＭＲＡＭでは、基板には、Ｓｉウエハ、石英、ＳＯＩ等平坦性の高い非磁性材料基板が用いられる。ＳＯＩ基板の作製方法はＥＬＴＲＡＮ法、ＳＩＭＯＸ法など各種方式が適用できる。その際、基板表面のＳｉの結晶方位は（１００）が好ましい。

【００８２】前記基板上に磁気抵抗膜を形成する際、バッファ層は、第1磁性膜より下面の表面自由エネルギーを調整し、より平坦性の高い界面構造を実現する目的で挿入される。Ｔａ，Ｃｕ，Ｃｒ等の各種金属やＳｉＮ，SiO_2, Al_2O_3等の絶縁体が用いられるが、基板材料と磁気抵抗膜の材料の選び方によっては、挿入しなくてもよい。バッファ層の膜厚は、２～１０ｎｍの範囲が好適である。これは、成膜方法によっては２ｎｍより薄いと島状成長による膜質不均一の問題があり、一方、１０ｎｍより厚いと生産性低下の問題があるためである。

【００８３】スピン散乱膜の場合、非磁性層としては導体が用いられる。Ｃｕ、Ａｇ、Ａｕ、Ａｌ、Ｍｇ等が用いられるが、より好適にはＣｕが用いられる。非磁性層の膜厚は、１～１０ｎｍの範囲が好適である。これは、成膜方法によって１ｎｍ未満では、島状成長によるピンホール発生の恐れがあり、両磁性層の相互作用により磁気抵抗が発現しない場合があり、一方、１０ｎｍを超える場合には、両磁性層間の間隔が電子の平均自由行程に対し広すぎてスピン依存性散乱が減るため磁気抵抗が小さくなるためである。

【００８４】スピントンネル膜の場合、非磁性層としては絶縁体が用いられる。絶縁体としては、Ａｌ、Ｓｉ、

Ｃｕ、Ｍｇ等の酸化物や窒化物が用いられるが、フェルミ準位が他の磁性層に近いＡｌ酸化物がより好適に用いられる。非磁性層の膜厚は、０．５～５ｎｍの範囲が好適である。これは、成膜方法によって０．５ｎｍ未満では、島状成長によるピンホール発生の恐れがあり、両磁性層の相互作用により磁気抵抗が発現しない場合があり、一方、５ｎｍを超える場合には、両磁性層間の間隔が電子の平均自由行程に対し広すぎてトンネリング確率が減るため磁気抵抗が小さくなるためである。

【００８５】磁気抵抗膜の構成要素である第１磁性層と第２磁性層の組み合わせは軟磁性材料と硬磁性材料からなり、第１磁性層が軟磁性層、第２磁性層が硬磁性層とする組み合わせのみでなく、第１磁性層が硬磁性層、第２磁性層が軟磁性層とする組み合わせを用いても良い。軟磁性材料は容易に磁化が反転するため再生層として機能する。硬磁性材料は軟磁性材料と比べ、磁化が反転しにくいためメモリ層として機能する。なお、本発明において、軟磁性材料と硬磁性材料の区別は２つの強磁性層間における保磁力の大小関係で定義されるもので、相対的に保磁力が大きいものを硬磁性材料とする。

【００８６】また、第1磁性層、第2磁性層とは機能を示すもので、各磁性層自体は単一元素から成る単層の場合もあるが各種合金の多層構造でも良い。例えば、硬磁性材料として機能させるために第１（あるいは第２）磁性層として、厚さ５ｎｍのＣｏと厚さ３０ｎｍのＦｅＭｎの二層構造としてピン止めしたものを用いることができる。第１磁性層および第２磁性層としては、Ｎｉ、Ｆｅ、Ｃｏ、ＮｉＦｅ、ＮｉＦｅＣｏ、ＦｅＣｏ、ＣｏＦｅＢといった強磁性材料や、ＴｂＦｅ、ＴｂＦｅＣｏ、ＧｄＦｅ等のフェリ磁性体が用いられる。これら二磁性層の組成は、その保磁力が異なるよう適宜調整される。第１磁性層、第２磁性層の膜厚は、２～１００ｎｍの範囲に選択するのが好適である。

【００８７】垂直磁化膜の場合には、磁化の方向は、形状的に最も反磁界が大きい膜面垂直方向を向いており、垂直磁気異方性を示す時点で既に最大の反磁界係数に打ち勝っている。そのため、素子を微細化した場合でもカーリングは発生しにくい。また、面内磁化膜のように、カーリングを防止するため平面的な形状を長方形とする必要もないため、メモリセル部の集積度を向上する上では、垂直磁化膜は面内磁化膜と比べ有利である。

【００８８】図１３は、強磁性層として垂直磁化膜を用いたスピントンネル構造の構成例を示す図である。図１３では、第1磁性層１１、非磁性層１２、第2磁性層１３からなる磁気抵抗膜１０に重畳して非磁性層６４及び磁化固定層６２がある。基板１と磁気抵抗膜１０との間には導体線７１が、磁化固定層６２の上には導体線７２があり、それぞれ下部センス線、上部センス線として機能する。信号再生するセンス電流は導体線７１、磁気抵抗膜１０、非磁性層６４、磁化固定層６２、導体線７２間を流れる。絶縁膜を介して導体線５１があり、電流磁界を磁気抵抗膜近傍で発生するワード線として機能する。第１磁性層１１と磁化固定層６２とが位置的に近くにあれば、磁気抵抗膜と磁化固定層の積層順は逆であっても構わない。

【００８９】図１３には、電流磁界が近似的にゼロの状態において、磁化固定層６２の働きで、第１磁性層１１の磁化方向が同じ向きに固定されている様子を矢印を用いて模式的に表している。磁化固定層６２、第１磁性層１１、第２磁性層１３の中の矢印は、それぞれの磁化方向を示している。信号再生の場合には、導体線５１に流すワード電流による磁界と、センス電流による磁界の合成磁界によって第１磁性層１１の向きが反転し、第２磁性層の磁化方向との組み合わせにより、“０”、“１”の状態が判断できる。この場合、磁化固定層６２と第１磁性層１１との間に働く磁気的結合力の大きさは、非磁性層６４の厚さを変えることによって調整する。非磁性層６４の膜厚は、２ｎｍ～２０ｎｍの範囲に選択することが好適である。これは、磁化固定層６２の材料や膜厚にもよるが、２ｎｍ未満であると、磁化固定層６２と第１磁性層１１との磁気的結合力が大きくなり過ぎてしてしまい、第１磁性層１１にかかる磁化固定層６２の影響が大きくなりすぎて再生に必要なワード電流が増えてしまう。一方、２０ｎｍを超えると、磁化固定層６２の効果が得られにくいため、磁化固定層６２の体積を増やして磁化を大きくしたり、単位体積当たりの磁化が大きい磁性材料に変更する必要があるためである。

【００９０】垂直磁化膜を用いた場合にも、膜厚、材料など適宜条件を選択することにより、ワード電流を正負の双方向に振らなくても、あらかじめ外部磁界を印加して設定した初期化磁化方向と反対の磁界を発生する正または負電流パルスのみで信号の再生ができる。

【００９１】第1磁性層／非磁性層／第2磁性層からなる磁気抵抗膜はメモリセルとして機能するが、その接合面積の大きさは用いるプロセスや使用用途に応じて適宜決定される。磁気抵抗膜の面積で規格化した抵抗率は１０－5Ωcm2程度なので、メモリセルを駆動するトランジスタのオン抵抗の値（数kΩ）に対し適合する１μm2以下が好適である。

【００９２】磁気抵抗膜上の導体線との間に設ける絶縁層には、ＳｉＯ2やＳｉＮ、Ａｌ2Ｏ3などの無機材料やノボラック樹脂などの有機材料が用いられる。絶縁層の膜厚は、センス線やワード線に印加する電力に対して必要な絶縁耐圧で決まるものであり、５～１０００ｎｍの範囲に選択すると好適である。

【００９３】情報の書き込みは、スピン散乱膜の場合、センス電流とワード電流の発生する合成磁界により行う。スピントンネル膜の場合、上下センス線のいずれか、もしくは両者に流すセンス電流を使って磁界を発生させてメモリ層の磁化方向を決定することで実現され

る。あるいは、絶縁層を介して設けられたワード電流による磁界を用いてもよい。ワード線を使う場合は、より確実に記録を行うことができる。

【００９４】導体線には、ＡｌやＣｕ、Ａｕなど導電性の高い材料が用いられる。導体線の膜厚は、印加する電流や線幅で決まりものであり、１００～１０００ｎｍの範囲に選択され、導体線は、情報の記録や再生に用いられる。

【００９５】上記の各材料・層に対する加工作業は、フォトリソグラフィーに代表される微細加工パターニング技術で容易に行なうことができる。成膜工程は、蒸着、スパッタリング、ＭＢＥ等の公知の各種方法が適用できる。

【００９６】

【実施例】以下に実施例を挙げて、本発明をより具体的に説明する。なお、以下の実施例は、本発明の最良の実施の形態の一例ではあるものの、本発明は、これら実施例により限定を受けるものではない。

【００９７】（実施例１）図１に、本実施例で用いた本発明のＭＲＡＭの構造の一例を示す。図1は、面内磁化膜のスピン依存散乱型磁気抵抗膜に対し、この磁気抵抗膜と同じ層構成の磁化固定層を設けた構成を示している。１の基板としてＳｉウエハ、１１、２１、３１の第1の強磁性層としてＮｉ８０Ｆｅ２０、１２、２２、３２の非磁性層としてＣｕ、１３、２３、３３の第2の強磁性層としてＣｏを用いる。１１、１２、１３を合わせて磁気抵抗膜１０が、２１、２２、２３を合わせて磁気固定層２０が、３１、３２、３３を合わせて磁気固定層３０が形成されている。４１のバッファ層としてＳｉＮ、５１の導体線としてＡｌを用いている。導体線５１は、磁気抵抗膜１０の直上に図示しない絶縁層ＳｉＮを介して存在しており、図1では見易くするため５１aと５１bに分割して表示している。

【００９８】素子の加工には、フォトリソグラフィとリフトオフを併用して素子パターンを形成した。図７（ａ）～（ｆ）は、その加工手順を示す図である。図７（ａ）と（ｂ）、図７（ｃ）と（ｄ）、図７（ｅ）と（ｆ）は、それぞれ対をなし、各工程毎に、図７（ａ）、（ｃ）、（ｅ）にその平面図、図７（ｂ）、（ｄ）、（ｆ）が前記平面図中のＸ－Ｘ′線での断面図をそれぞれ示してある。

【００９９】まず、図７（ａ）に示す、長さＬ＋２Ｐ、幅Wの素子パターンに成膜をするため、同形状のレジストマスクをフォトリソグラフィで作製する。成膜マスクを設けた基板をスパッタ装置に入れ、成膜する。到達圧力５×１０－５Ｐａ以下の条件で、バッファ層４１であるＳｉＮ、第１磁性層１１、２１、３１であるＮｉ８０Ｆｅ２０、非磁性層１２、２２、３２であるＣｕ、第２磁性層１３、２３、３３であるＣｏを順次成膜する。その膜厚は、ＳｉＮは１０ｎｍ、Ｎｉ８０Ｆｅ２０は１０ｎｍ、Ｃｕは５ｎｍ、Ｃｏは１０ｎｍである。ここで、第１磁性層のＮｉ８０Ｆｅ２０は軟磁性材料であり再生層として、第２磁性層のＣｏは硬磁性材料でありメモリ層として機能する。成膜時には、基板表面方向に同じ磁気異方性を持つよう永久磁石を配置してある。永久磁石の発生する磁界強度は、測定中心で２０Ｏｅとした。成膜後、アセトンで超音波洗浄を行い、レジスト上に堆積している余分な膜をレジストと同時に除去して、リフトオフすることにより、図７（ｂ）に断面形状を示す積層構造が得られる。

【０１００】次に、図７（ｃ）に示す平面形状の絶縁膜となるように、レジストマスクをフォトリソグラフィで作製する。マスクを設けた基板をスパッタ装置に入れ、ＳｉＮを厚さ３５０ｎｍ成膜する。成膜後、アセトンで超音波洗浄を行い、レジスト上に堆積している余分なＳｉＮ膜をレジストと同時に除去して、リフトオフすることにより、図７（ｄ）に断面形状を示す絶縁膜ＳｉＮが得られる。

【０１０１】次に、図７（ｅ）に示す平面形状の導体線５１とプローブパットとなるように、レジストマスクをフォトリソグラフィで作製する。マスクを設けた基板をスパッタ装置に入れ、Ａｌを厚さ４００ｎｍ成膜する。成膜後、アセトンで超音波洗浄を行い、レジスト上に堆積している余分なＡｌ膜をレジストと同時に除去して、リフトオフすることにより、図７（ｆ）に断面形状を示す導体線５１とプローブパットが得られ、所望の素子が完成する。磁気抵抗膜の両端に接触するよう成膜した１００μm角のＡｌ膜は、磁気抵抗を測定するプローブ針を落とすパッドとして機能する。

【０１０２】上述した作製方法を用いて、センス線の磁化容易軸方向の長さL、困難軸方向の長さW、及びその周囲に存在する磁化固定層の長さＰの組み合わせが異なるサンプルを多数作製した。

【０１０３】上記のプロセスを経て作製したメモリ素子に対し、アクセス信号を出して素子特性を評価した。センス電流５ｍＡを流し、磁気抵抗膜の抵抗変化を電圧変動としてオシロスコープで捉えた。リード線での残留抵抗やパッド・プローブ間の接触抵抗の影響を排除するため、電圧検出には４端子測定法を用いて、電圧差はオシロスコープの差分機能を使って測定した。ワード線（導体線５１）には周期1msの矩形波電流信号を入力し、ワード線信号に応じて発生する磁界と一定なセンス電流による発生磁界との合成磁界で情報の再生、記録を行った。

【０１０４】図８は、再生時における、ワード線信号と磁気抵抗膜の抵抗変化に相当する電圧変動の測定波形の一例である。Ｌ＝２０μｍ、Ｗ＝２０μｍ、Ｐ＝６０μｍ、Ｐ／Ｌ＝３に選択した素子に対し、センス電流５ｍＡ、ワード電流８０ｍＡの条件で読み出した“０”と“１”の信号波形を、それぞれ図８（ａ）、（ｂ）に示

す。上段がセンス電圧（磁気抵抗膜の抵抗変化に相当）、下段がワード電流の時間変化を示す。ワード電流は電流プローブで読み出しており変換係数は、１００ｍＡ＝１０ｍＶである。図８中、「1→」で図示したワード電流のゼロレベルよりプラス側のワード電流のみで、記録情報“０”、“１”に合わせてセンス電圧の波形が変化しており、センス電圧の立ち上がりを微分検出することで、“０”、“１”が識別可能となる。

【０１０５】Ｌ，Ｐの異なる複数種のサンプル（メモリ素子）に対し、プラス側の電流のみで信号再生が可能かどうかを比較し、その結果を表１に示す。以上の結果から、Ｐ／Ｌが２．５以上の素子において、プラス側のワード電流のみで信号の再生が可能であることがわかる。従って、これらＰ／Ｌが２．５以上のサンプルでは、バイポーラ電源を用いることなく信号の再生が可能である。

【０１０６】

【表１】

P／L	P（μｍ）	L（μm）	ΔVｓ（mV）	再生の可否
０．５	１０	２０	—	×
１	２０	２０	—	×
１．５	３０	２０	—	×
２	４０	２０	—	×
２．５	５０	２０	2.2	○
３	６０	２０	2.2	○
３．５	７０	２０	2.5	○
４	８０	２０	2.1	○
４．５	９０	２０	2.3	○
５	１００	２０	2.3	○

【０１０７】（実施例２）図２に、本実施例における本発明のＭＲＡＭの他の構成例を示す。図２の素子構成では、面内磁化膜によるスピン依存散乱型の磁気抵抗膜に対し、この磁気抵抗膜とは異なった層構成の磁化固定層を設けている。１は基板、１１は第1の強磁性層、１２は非磁性層、１３は第２の強磁性層である。１１、１２、１３を合わせて磁気抵抗膜１０が形成されている。４１はバッファ層、５１は導体線を示す。導体線５１は磁気抵抗膜１０の直上に絶縁層（図示しない）を介して存在し、図２では見易くするため５１aと５１bに分割して表示している。磁化固定層６２、６３が図面X方向に磁気抵抗膜１０の側壁に形成されている。このようなサンプルに対し、情報の記録再生は矢印１００の方向に磁化固定層６２、磁気抵抗膜１０、磁化固定層６３の順に流れるセンス電流と導体線５１を矢印１０１a、１０１bの方向に流れるワード電流の発生する合成磁界によって行われる。

【０１０８】磁化固定層の材料をＣｏに変更した以外は、実施例１のメモリ素子と同じ材料、膜厚を選択し、スパッタ成膜とリフトオフ工程を組み合わせて、メモリ素子を作製した。実施例１のメモリ素子と異なり、磁化固定層の材料が磁気抵抗膜と異なる材料のため、この磁化固定層形成用のフォトリソグラフィ工程を1回増やす必要がある。

【０１０９】Ｌ，Ｐの異なる複数種のサンプル（メモリ素子）に対し、実施例１と同様の手法でセンス電流とワード電流を印加して記録再生を行い、プラス側の電流のみで信号が再生可能かどうかの検証を行なった。表２にその結果を示す。強磁性体のＣｏを磁化固定層に用いることで、実施例１の磁気抵抗膜と同じ層構成の磁化固定層を用いる素子と比べ、Ｐ／Ｌが小さくてもプラス側のワード電流のみで信号の再生が可能であることが確認された。従って、磁化固定層の長さＰを短くでき、より高い集積度を達成できる構造であることがわかった。磁化固定層に使用する材質や膜厚を適宜調整することで所望の特性を得ることが可能である。

【０１１０】

【表２】

P／L	P（μｍ）	L（μm）	ΔVｓ（mV）	再生の可否
０．５	１０	２０	—	×
１	２０	２０	２．２	○
１．５	３０	２０	２．３	○
２	４０	２０	２．２	○
２．５	５０	２０	２．１	○
３	６０	２０	２．２	○
３．５	７０	２０	２．３	○
４	８０	２０	２．２	○
４．５	９０	２０	２．１	○
５	１００	２０	２．２	○

【０１１１】（実施例３）図３に本実施例における本発明のＭＲＡＭの他の構成例を示す。図３に示す素子構成は、面内磁化膜によるスピントンネル型の磁気抵抗膜を用い、この磁気抵抗膜と同じ層構成の磁化固定層を設け

た素子構造の一例である。１は基板、１１、２１、３１は第1の強磁性層、１２、２２、３２は非磁性層、１３、２３、３３は第2の強磁性層である。１１、１２、１３を合わせて磁気抵抗膜１０が、２１、２２、２３を合わせて磁化固定層２０が、３１、３２、３３を合わせて磁化固定層３０が形成されている。７１、７２は導体線を示す。導体線７１は第１磁性層１１、２１、３１に、導体線７２は第２磁性膜１３に電気的に接続している。さらに、導体線７２の上に絶縁膜を介して導体線７２と同方向にワード線を設けている（不図示）。導体線７１と７２はそれぞれ、下部センス線、上部センス線として働き、センス電流は下部センス線から磁気抵抗膜１０を通過して上部センス線に流れる。情報の記録再生は、センス線とワード線に流れる電流が発生する合成磁界によって行われる。

【０１１２】素子の加工には、フォトリソグラフィとリフトオフを使用した。磁気抵抗膜の磁化容易軸Ｘ方向の長さをＬ、幅をＷとし、磁気抵抗膜１０と磁化固定層３０（ならびに磁化固定層２０）とのＸ方向の間隔をＰ１、磁化固定層３０（ならびに磁化固定層２０）のＸ方向の長さをＰ２として、各幅Ｗについて、Ｌ，Ｐ１，Ｐ２の長さを変えたサンプルを多数作製した。

【０１１３】各材料膜の成膜にはスパッタ装置を用いて、到達圧力５×１０－５Ｐａ以下で、導体線７１のＡｌ、第１磁性層１１、２１、３１のＮｉ８０Ｆｅ２０、非磁性層１２、２２、３２のＡｌＯｘ、第２磁性層１３、２３、３３のＣｏ、絶縁膜のＳｉＮ、導体線７２のＡｌの各膜を成膜した。膜厚はそれぞれ、導体線７１のＡｌを２５ｎｍ、第１磁性層のＮｉ８０Ｆｅ２０を２５ｎｍ、非磁性層のＡｌＯｘを１．２ｎｍ、第２磁性層のＣｏを２５ｎｍ、導体線７２のＡｌを５０ｎｍ、絶縁膜のＳｉＮを１１０ｎｍとした。ここで、第１磁性層のＮｉ８０Ｆｅ２０は軟磁性材料であり再生層として、第２磁性層のＣｏは硬磁性材料でありメモリ層として機能する。非磁性層であるＡｌＯｘの作製には、はじめＡｌをスパッタした後、装置内に酸素を導入して１０００Ｐａで１２５分放置してＡｌＯｘ酸化膜を形成した。このＡｌの酸化膜の形成後、所定の到達圧力まで真空排気をして導入された酸素を除き、次のＣｏ膜の成膜を行った。成膜時には、基板表面方向に同じ磁気異方性を持つよう永久磁石を配置してある。永久磁石の発生する磁界強度は、測定中心で２００Ｏｅとした。

【０１１４】Ｌ，Ｐ１、Ｐ２の異なる複数種のサンプル（メモリ素子）に対し、実施例１と同様の手法でセンス電流とワード電流を印加して記録再生を行い、プラス側の電流のみで信号が再生可能かどうかの検証を行なった。表３にその結果を示す。スピントンネル型の磁気抵抗膜を用いる構成でも、磁化固定層２０、３０を設け、Ｐ２／Ｌを２．５以上とすることでプラス側の電流のみで信号が再生可能であることを確認した。

【０１１５】

【表３】

Ｐ２／Ｌ	Ｐ２（μｍ）	Ｐ１（μｍ）	Ｌ（μｍ）	ΔＶｓ（ｍＶ）	再生の可否
０．５	１０	０．５	２０	－	×
１	２０	０．５	２０	－	×
１．５	３０	０．５	２０	－	×
２	４０	０．５	２０	－	×
２．５	５０	０．５	２０	７．１	○
３	６０	０．５	２０	７．２	○
３．５	７０	０．５	２０	７．５	○
４	８０	０．５	２０	７．５	○
４．５	９０	０．５	２０	７．７	○
５	１００	０．５	２０	７．５	○

【０１１６】（実施例４）図４に、本実施例における本発明のＭＲＡＭの他の構成例を示す。図４に示す素子構成では、面内磁化膜によるスピントンネル型の磁気抵抗膜に対し、この磁気抵抗膜とは異なった材料からなる磁化固定層を設けている。１は基板、１１は第1の強磁性層、１２は非磁性層、１３は第2の強磁性層である。１１、１２、１３を合わせて磁気抵抗膜１０が形成されている。磁化固定層６２、６３が磁気抵抗膜の側壁Ｘ方向に形成されている。７１、７２は導体線を示す。導体線７１は第1磁性層１１に、導体線７２は第2磁性膜１３に電気的に接続している。さらに、導体線７２の上に絶縁膜を介して導体線７２と同方向にワード線を設けている（不図示）。導体線７１と７２はそれぞれ、下部センス線、上部センス線として働き、センス電流は下部センス線から磁気抵抗膜１０を通過して上部センス線に流れる。情報の記録再生はセンス線とワード線に流れる電流が発生する合成磁界によって行われる。

【０１１７】素子の加工には、フォトリソグラフィとリフトオフを使用した。磁気抵抗膜の磁化容易軸Ｘ方向の長さをＬ、幅をＷとし、磁気抵抗膜１０と磁化固定層６３（ならびに磁化固定層６２）とのＸ方向の間隔をＰ１、磁化固定層６３（ならびに磁化固定層６２）のＸ方向の長さをＰ２として、各幅Ｗについて、Ｌ、Ｐ１、Ｐ２の長さを変えたサンプルを多数作製した。

【０１１８】磁化固定層の材料をＣｏに変更した以外は、実施例３のメモリ素子と同じ材料、膜厚を選択し、

スパッタ成膜とリフトオフ工程を組み合わせて、メモリ素子を作製した。実施例３のメモリ素子と異なり、磁化固定層の材料が磁気抵抗膜と異なる材料のため、この磁化固定層形成用のフォトリソグラフィ工程を1回増やす必要がある。

【０１１９】Ｌ、Ｐ１、Ｐ２の異なる複数種のサンプル（メモリ素子）に対し、実施例１と同様の手法でセンス電流とワード電流を印加して記録再生を行い、プラス側の電流のみで信号が再生可能かどうかの検証を行なった。表４にその結果を示す。磁化固定層６２、６３を設け、Ｐ２／Ｌを１．５以上とすることでプラス側の電流のみで信号が再生可能であることを確認した。磁化固定層と磁気抵抗膜の間隔Ｐ１が同じ場合、実施例３の磁気抵抗膜と同じ層構成の磁化固定層を用いる素子と比べ、強磁性体のＣｏを磁化固定層に用いる本実施例では、磁化固定層の長さＰ２がより小さくてもプラス側のワード電流のみで信号の再生が可能であることが確認される。従って、隣接する磁気抵抗膜間の隔たり（Ｐ１＋Ｐ２＋Ｐ１）を短くでき、より高い集積度を達成できる構造であることがわかった。磁化固定層に用いる材質や膜厚を適宜調整することで所望の特性を得ることが可能である。

【０１２０】

【表４】

Ｐ２／Ｌ	Ｐ２（μｍ）	Ｐ１（μｍ）	Ｌ（μｍ）	ΔＶｓ（ｍＶ）	再生の可否
０．５	１０	０．５	２０	－	×
１	２０	０．５	２０	－	×
１．５	３０	０．５	２０	７．２	○
２	４０	０．５	２０	６．９	○
２．５	５０	０．５	２０	７．５	○
３	６０	０．５	２０	７．１	○
３．５	７０	０．５	２０	７．５	○
４	８０	０．５	２０	７．２	○
４．５	９０	０．５	２０	７．３	○
５	１００	０．５	２０	７．４	○

【０１２１】（実施例５）図１４に、本実施例における本発明のＭＲＡＭの他の構成例を示す。図１４は、垂直磁化膜を用いたスピントンネル型の磁気抵抗膜に対し、この磁気抵抗膜を形成する磁性膜とは異なる構成の磁化固定層を設けた素子構造の例を示している。１は基板、１１は第1の強磁性層、１２は非磁性層、１３は第2の強磁性層である。１１、１２、１３を合わせて磁気抵抗膜１０が形成されている。この磁気抵抗膜１０の第２の強磁性層１３上に、磁化固定層６２及び非磁性層６４が重畳されている。７１、７２は導体線を示す。導体線７１は第２磁性層１３に、導体線７２は磁化固定層６２に電気的に接続している。さらに、磁気抵抗膜１０の側面に絶縁膜を介して導体線７２と同方向にワード線として機能する導体線５１を設けている。導体線７１と７２はそれぞれ、下部センス線、上部センス線として働き、センス電流は下部センス線から磁気抵抗膜１０を通過して上部センス線に流れる。情報の記録再生は、センス線とワード線に流れる電流が発生する合成磁界によって行われる。素子の加工には、通常の半導体製造プロセスを使用した。

【０１２２】各材料膜の成膜は、スパッタ装置を用いて、到達圧力５ｘ１０－５Ｐａ以下で、導体線７１のＡｌ、第１磁性層１１のＧｄ２１Ｆｅ７９、非磁性層１２のＡｌＯｘ、第２磁性層１３のＧｄ２１Ｆｅ７９、絶縁膜のＳｉＮ、導体線７２のＡｌ、非磁性層６４のＣｕ、磁化固定層６２のＴｂ26Ｆｅ74の各膜を成膜した。膜厚はそれぞれ、導体線７１のＡｌを２５nm、第１磁性層１１のＧｄ２１Ｆｅ７９を１５nm、非磁性層１２のＡｌＯｘを２．２nm、第２磁性層１３のＧｄ２１Ｆｅ７９を４０nm、導体線７２のＡｌを５０nm、絶縁膜のＳｉＮを６０nm、非磁性層６４のＣｕを５nm、磁化固定層６２のＴｂ26Ｆｅ74を50nmとした。ここで、第１磁性層１１は再生層として、第２磁性層１３はメモリ層として機能する。非磁性層１２であるＡｌＯｘの作製には、はじめＡｌをスパッタした後、装置内に酸素を導入して１０００Ｐａで１２５分放置してＡｌＯｘ酸化膜を形成した。このＡｌの酸化膜の形成後、所定の到達圧力まで真空排気をして導入された酸素を除き、次のＧｄ２１Ｆｅ７９膜の成膜を行った。

【０１２３】Ｌ、Ｗの異なる複数種のサンプル（メモリ素子）に対し、実施例１と同様の手法でセンス電流とワード電流を印加して記録再生を行い、プラス側の電流のみで信号が再生可能かどうかの検証を行なった。表５に、センス電流１mAとした際の結果を示す。磁化固定層６２を設けることで、プラス側の電流のみで信号が再生可能であることを確認した。表５に示す結果は、磁気抵抗膜の平面形状（面積）に依存して、センス電流１mAとした際の信号サイズは、面積に反比例して変化することを表している。

【０１２４】また、本実施例においては、磁化固定層と磁気抵抗膜との間に、非磁性層としてＣｕをはさんだ構成をとっているが、この非磁性層は、磁気抵抗膜における、磁化固定層の磁界の大きさを制御するために設けられたものであり、磁化固定層の材料、膜厚を適宜選択す

ることによって、磁化固定層の磁界の大きさを調整し、この非磁性層を省くことも可能ではある。

【０１２５】

【表５】

L／W	W（μm）	L（μm）	ΔVs（mV）	再生の可否
1	5	5	412	○
1	10	10	108	○
2	10	20	65	○
1	20	20	23	○
1	30	30	11	○

【０１２６】

【発明の効果】以上述べたとおり、本発明の効果は、ＭＲＡＭの再生層の近傍に磁化固定層を設けることで、信号を再生する際の電流磁場を発生させる電流の印可方向を正負に切り替えることなく、プラス側もしくはマイナス側のパルス電流のみで再生が可能になることである。このため、信号検出は、正負いずれか一方のパルス電流を供給するだけですむので、再生専用機においては、従来の再生装置と異なり、バイポーラ電源が不要となる利点を生み、装置の小型化も図られる。結果として、低コスト化が図られ、安価なメモリ装置、それ用の不揮発性固体メモリの提供が可能となる。

【図面の簡単な説明】

【図１】本発明の磁気抵抗膜と同じ層構造の磁化固定層を設けたＭＲＡＭ（スピン散乱型）の構成例を模式的に示す斜視図である。

【図２】磁気抵抗膜のスピン散乱膜以外の磁性材料からなる磁化固定層を設けたＭＲＡＭ（スピン散乱型）の構成例を模式的に示す斜視図である。

【図３】本発明の磁気抵抗膜と同じ層構造の磁化固定層を設けたＭＲＡＭ（スピントンネル型）の構成例を模式的に示す斜視図である。

【図４】磁気抵抗膜のスピントンネル膜以外の磁性材料からなる磁化固定層を用いた本発明のＭＲＡＭ（スピントンネル型）の構成例を模式的に示す斜視図である。

【図５】ＭＲＡＭの動作原理を説明する模式図であり、（ａ）はＭＲＡＭ（スピン散乱型）の構成例、（ｂ）、（ｃ）は信号記録、（ｄ）～（ｇ）は信号再生の動作原理を説明する図である。

【図6】ＣＩＰ構造とＣＰＰ構造におけるセンス電流の導通方法を模式的に示す斜視図である。

【図7】実施例１のＭＲＡＭ（スピン散乱型）の作製プロセスを説明する図であり、（ａ）と（ｂ）はパターン化された磁気抵抗膜の成膜工程、（ｃ）と（ｄ）は絶縁膜の成膜工程、（ｅ）と（ｆ）は導体線とプルーブ・パッド用金属膜の成膜工程を示す。

【図8】実施例1のＭＲＡＭ（スピン散乱型）における再生時信号波形の一例を示す図であり、（ａ）は“０”状態、（ｂ）は“１”状態における信号波形を示す。

【図9】実施例１のＭＲＡＭ（スピン散乱型）における、電流磁場Ｈ≒０における磁化状態を模式的に示す図であり、（ａ）は“０”状態、（ｂ）は“１”状態を示す。

【図１０】実施例４のＭＲＡＭをアレイ化した構成を模式的に示す斜視図である。

【図１１】従来のＭＲＡＭにおける磁界－ＭＲ比マイナーループを模式的に示す図である。

【図１２】本発明のＭＲＡＭにおける磁界－ＭＲ比マイナーループの模式的に示す図である。

【図１３】本発明の垂直磁化膜によるスピントンネル構造のＭＲＡＭの構成を模式的に示す断面図である。

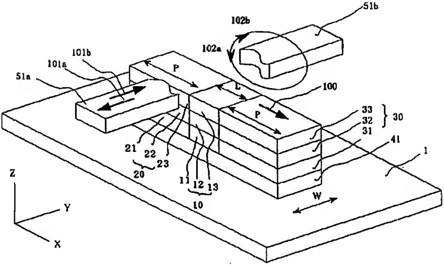
【図１４】本発明の垂直磁化膜によるスピントンネル構造のＭＲＡＭの一例である、実施例５のＭＲＡＭの構成を模式的に示す斜視図である。

【符号の説明】

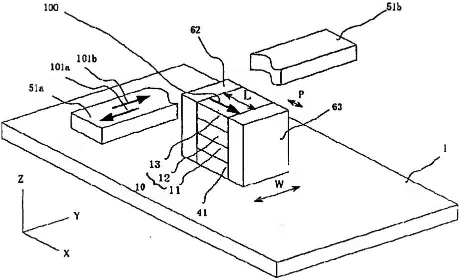
１　基板
１０　磁気抵抗膜
１１　第１磁性層
１２　非磁性層
１３　第２磁性層
２０　磁化固定層
２１　第１磁性層
２２　非磁性層
２３　第２磁性層
３０　磁化固定層
３１　第１磁性層
３２　非磁性層
３３　第２磁性層
４１　バッファ層
５１　導体線
６２　磁化固定層
６３　磁化固定層
６４　非磁性層
７１　導体線
７２　導体線
１００　磁化の向き
１０１ａ　電流の向き
１０１ｂ　電流の向き
１０２ａ　発生する磁界の向き
１０２ｂ　発生する磁界の向き
１０２　磁気抵抗膜
１０３　磁気抵抗膜

２０２ 磁気抵抗膜
２０３ 磁気抵抗膜
３０２ 磁気抵抗膜
３０３ 磁気抵抗膜
６２３ 磁化固定層
７０１ 導体線
７０２ 導体線

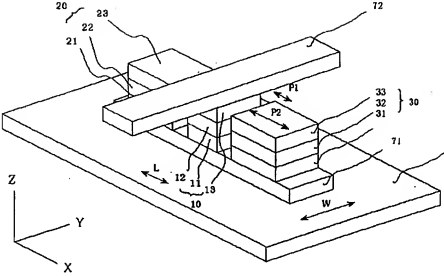
【図１】



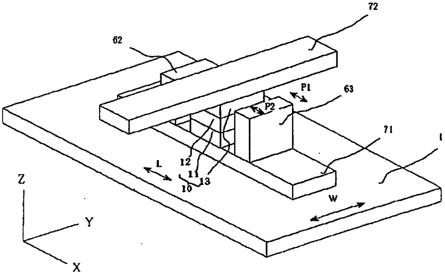
【図２】



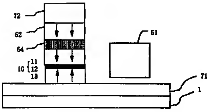
【図３】


20
23
22
21
72
P1
P2
33
32
31
30
71
1
L
12
11
13
10
W
Z
Y
X

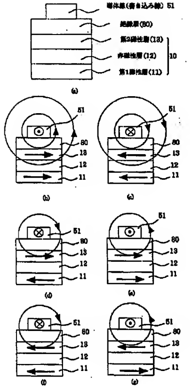
【図４】


72
62
P1
63
P2
71
1
L
12
11
13
10
W
Z
Y
X

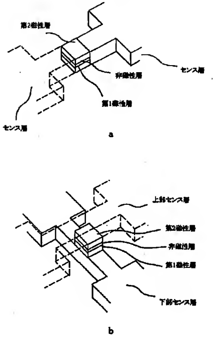
【図１３】


72
62
64
10
11
12
13
51
71
1

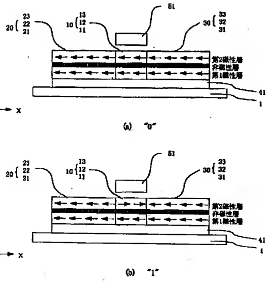
【図５】


導体線(書き込み線) 51
絶縁層(80)
第2磁性層(13)
非磁性層(12)
第1磁性層(11)
10
(a)
(b)
(c)
(d)
(e)
(f)
(g)

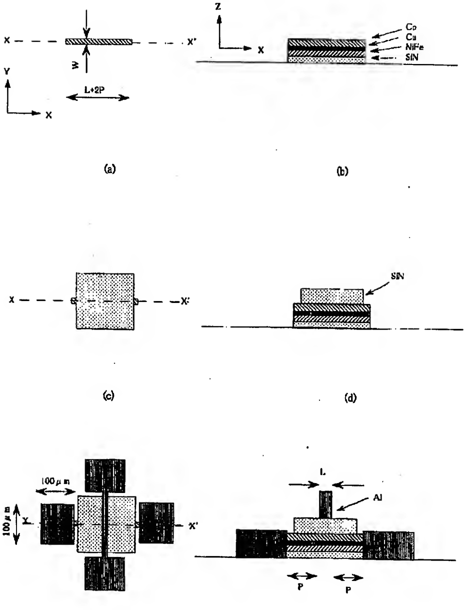
【図６】


第2磁性層
非磁性層
第1磁性層
センス層
センス層
a
上部センス層
第2磁性層
非磁性層
第1磁性層
下部センス層
b

【図９】


第2磁性層
非磁性層
第1磁性層
41
1
z
x
(a) "0"
(b) "1"

【図７】

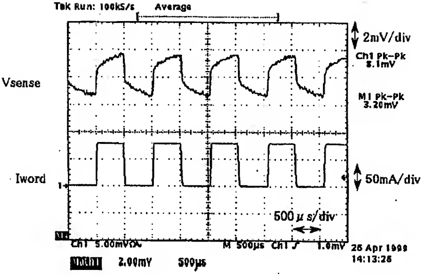


(a) (b)

(c) (d)

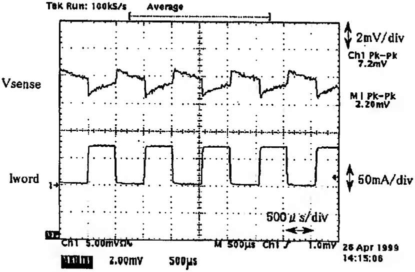
(e) (f)

【図8】



Tek Run: 100kS/s Average
Vsense
Iword
2mV/div
Ch1 Pk-Pk 8.1mV
M1 Pk-Pk 3.20mV
50mA/div
500 μ s/div
Ch1 5.00mV
M 500μs Ch1 ∫ 1.0mV
26 Apr 1999 14:13:26
2.00mV 500μs

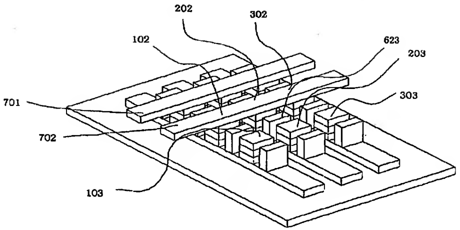
(a)



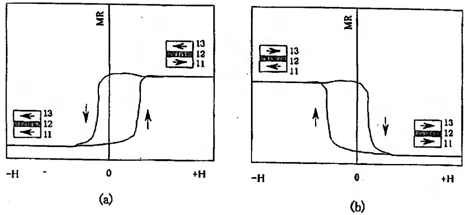
Tek Run: 100kS/s Average
Vsense
Iword
2mV/div
Ch1 Pk-Pk 7.2mV
M1 Pk-Pk 2.20mV
50mA/div
500 μ s/div
Ch1 5.00mV
M 500μs Ch1 ∫ 1.0mV
26 Apr 1999 14:15:06
2.00mV 500μs

(b)

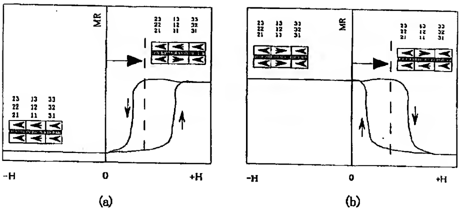
【図１０】


202
302
102
623
203
303
701
702
103

【図１１】


MR
13
12
11
-H
0
+H
(a)
(b)

【図１２】


MR
23
22
21
13
12
11
33
32
31
-H
0
+H
(a)
(b)

【図１４】